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The Paris Congress.

There were no less than 137 British visitors to the Paris International Foundry Congress, which number compares very favourably with domestic conferences, with the exception of Birmingham. From an international standpoint the most remarkable feature is the number of Spaniards present, as well over one hundred signed the register. The exhibition itself is only small, and the character of the exhibits are much the same as were exhibited at Birmingham. Of the outstanding features were a few French moulding machines designed to tackle a particular job or type of work.

Two types of sand mill attracted a good deal of attention, whilst a method of casting either solid or hollow metal rods was considered advantageous by the majority of the British visitors. The three British pig-iron exhibits were excellent of their type, and some fair business, especially with Spain, is reported.

The opening session was polyglot, and obviously took up much time. It is the type of meeting which should be kept as short as possible. The English-speaking session was distinctly interesting, especially the discussion on Dr. Moldenke's excellent resumé of the present position of testing cast iron. Mr. J. Shaw, of Sheffield, who opened the discussion, divided it into three sections—a consideration of the American Arbitration bar, the possibility of using the Firmont bar, and the necessity for various sizes of test bars. Dealing with the first, he pointed out that it only represented itself; that it was rarely used in the United States, and that oval bars were often tested there without correcting the result, so as to make it comparable. During the discussion the American delegates admitted that the arbitration bar was almost entirely confined to disputes, but they objected to the statement as to the non-correction for oval bars.

Dealing with the Firmont method of testing, Mr. Shaw pointed out that although this had been invented some fourteen years, it did not yet appear in any French specification of importance. Mons. Ronceray suggested that the non-exploitation of the test was due to the fact that Mons. Firmont was a scientific rather than a commercial man.

During the reply to the discussion on this section, Dr. Moldenke clearly showed that a small bar cut from any section only represents that particular position in the casting, and not the casting itself. Mr. Young's recent Paper in the section dealing with machinery allowances clearly proves this, if any proof were needed. Perhaps unnecessarily Mr. Shaw went over the arguments for the three-bar specification, which has been evolved by his committee. Again, it was pointed out that even this test, when cast-on, does not represent the casting—it only represents an average section.

Mr. Maybrey's Paper on Magnesium in the Foundry was of great practical interest, and the necessity for using pure metal was emphasised by Mr. Wesley Lambert, who stated that the samples in one of his specimen cases were kept bright and free from oxidation because of the presence of an impure sample of magnesium which contained deliquescent magnesium chloride in its composition, and so attracted any moisture present to itself.

Mr. Smalley's Paper on Mass Effect was of exceptional interest, and deal with an aspect of foundry work which will, in the future, have to form an essential part of the technical stock in trade for every foundry manager.

Mr. Holmes, in his Paper on the Testing of Moulding Sands, made a strong plea for the imposition of universal testing methods. It is a phase on which we have previously expressed the same view. Sand tests, unlike tensile tests or heat degrees, have not fixed that sense of comparison in the average technical mind, and which, when once formed, are almost impossible to replace. It is to be hoped that, whilst the subject is yet young, a series of standardised methods and expression of results will be fixed, so that these results will convey universally just as much as the giving of a man's weight in stones to a Britisher or in pounds to an American.

The social side of the Congress was in accordance with expectations, and, considering language difficulties, was carried through excellently.

The Mechanical Handling and Preparation of Sands.*

By H. M. Lane.

The sand problem of any foundry is made up of an almost endless number of small details, and each of these is of importance, and it is only by giving proper attention to all of the details that the greatest profit can be made in the production of castings. In this Paper we will deal only with the preparation of sand and its handling or transportation.

Every movement of material costs a certain amount of labour, and this labour represents a capital investment. To reduce the cost of castings we must try to reduce much unnecessary capital

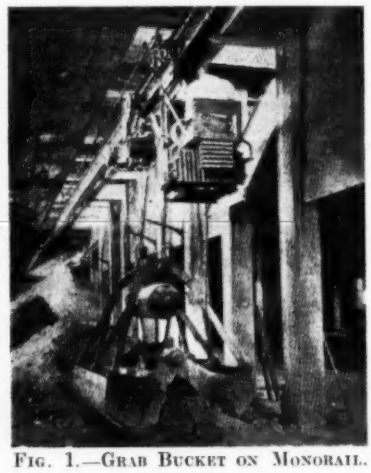


FIG. 1.—GRAB BUCKET ON MONORAIL.

investment. At the same time, we must consider the fact that to neglect the proper preparation of the sand it is likely to very largely increase the scrap loss.

The subject under consideration naturally divides itself into two main parts. These are sand transportation and sand preparation.

Preparation of Sand.

This subject naturally divides itself into two parts, first, facing sand or the sand to be placed next to the pattern plate, and second, backing sand or the sand necessary for filling the balance of the mould.

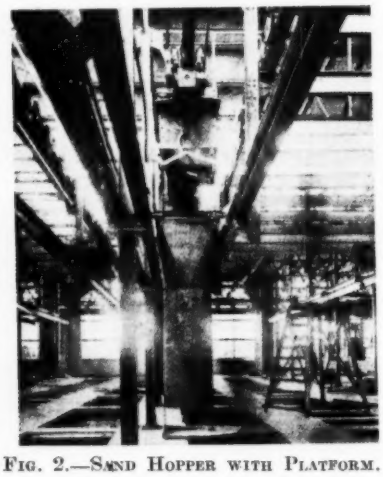


FIG. 2.—SAND HOPPER WITH PLATFORM.

The amount of facing sand required may be greatly reduced and in some cases its use entirely eliminated by the proper preparation of the entire mass of backing sand.

The total volume of facing sand is usually relatively small when compared with the volume of backing sand. The facing sand contains a large proportion of new sand, and in many cases all of the new sand which enters the sand heaps comes through as facing sand.

The theory of properly preparing a moulding sand can be summed up in a very few words, as follows:—The sand should be so treated that each grain is surrounded by a layer of bonding material, and this bonding material must be as uniform over the surface of the grains as is possible, and must constitute the thinnest layer possible consistent with the proper cohesion of the grains.

The bonding material usually consists of a highly colloidal clay, though in some cases, a portion of the bonding action comes from iron oxides, organic matter, or other material contained in the bonding portion of the sand.

When the grains are properly coated with bonding material they will adhere when forced into intimate contact.

There is one point, however, which is just as important as the coating of the sand grains, and that is, that after they are coated the individual grains should be separated so that each, so far as possible, is by itself, with a maximum amount of air between them. This condition insures a maximum amount of venting space after the grains are rammed into contact.

To accomplish the proper bonding of the sand it is necessary that the sand grains must be rubbed together in such a way as to uniformly distribute the bond over the face of the grains, but care must

FIG. 3.—FRONT VIEW OF BINS.

be exercised to see that the grains are not forced together or rubbed together with too great a pressure, which would tend to grind or to break the grains, and thus increase the amount of dust and reduce the diameter of the sand grains.

The sand grains themselves are preferably of pure quartz or silica, and are likewise as near spherical as possible. There are cases on record, however, of a very satisfactory moulding sand which contained a large proportion of grains other than quartz, but such moulding sand is usually short-lived, that is, it has to be renewed much more quickly than one in which all of the grains are wholly or almost wholly quartz.

The individual grains of sand in a mould should form a structure which is at the same time strong enough to resist metal pressure, the handling of the mould, and to afford a surface to support cores. On the other hand, it must permit the relatively free passage of gas from the mould during the pouring operations. To accomplish this the grains should be of as uniform a size as possible.

The size of the grains to a large extent is determined by the character of the metal to be poured in the mould, and the smoothness of the surface required on the casting. Some metals have a more searching action on sand, that is, the metal is of such a nature that it tends to flow between the sand grains to a greater extent. To counteract this tendency it may be necessary to use finer grains or sand, or to resort to some certain facing on the interior of the mould.

*A Paper presented to the Paris Foundry Congress

The ideal preparation of facing sand is to have the new sand in such a condition that it can be readily blended throughout the mass, and to use a suitable amount of new and old sand, together with sea coal and in some cases other ingredients, sometimes of an organic nature. If the new moulding sand is of such a nature that it persists in forming lumps it may be necessary to dry the sand and then to break up the lumps with suitable machinery, and to sift the sand.

One very successful stove foundry in the United States uses no sand-mixing machinery, and no facing sand, with the exception of an automatic sand cutter for cutting the heaps on the floor, but the new sand is dried, passed through rolls, and

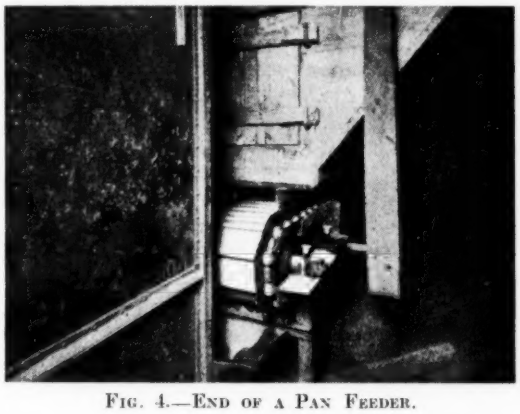


FIG. 4.—END OF A PAN FEEDER.

then bolted through a fine screen before it is introduced into the sand heaps. This fine sand is simply scattered over the sand heaps before they are cut over. This plant uses practically no cores, so that the sand heaps are not deteriorated by the constant introduction of burnt core sand, and they use care in taking away the castings to see that they do not shake off more burnt sand than they can help.

The above mentioned practice is a decided exception, and yet this foundry is noted for the smooth, fine character of castings produced.

The selection of sand-mixing equipment itself will be determined quite largely by the volume to be handled. For facing sand some form of pan mill has been found to give the best results, but for general backing sand it seems to be sufficient to first remove any foreign material such as scrap, pieces of cores, etc. from the sand by sifting, and then to pass the material through a properly designed pug mill or paddle mixer in which moisture is added to give it the proper temper. The sand should then be passed to storage through a centrifugal disintegrator or mixer which will separate the grains very thoroughly, or the disintegrator may be placed beyond the general sand storage, the sand being passed through it just before it is taken to the moulders.

There is one law of chemistry, however, that we cannot neglect, and that is the time law. The colloidal matter which forms the bond is in the nature of a sponge, and it takes a certain definite amount of time for the moisture to thoroughly permeate this, and get it in its best possible condition, and at the same time the temperature of sand must be reduced to such a point that the vapour tension of the moisture will be such that there is not a tendency to produce fog or mist in the vent spaces between the sand grains.

More sand handling plants and continuous foundries have been a failure on account of the lack of recognising these two conditions, than from all other causes put together. It is very essential that any kind of sand, either for facing sand or backing sand, should be given time to come to its best condition in a mass before it is used.

Sand Handling.

The incoming or new sand which enters a plant is in relatively small volume compared with the sand that must be handled in the making of castings. For instance, in the United States, in making certain classes of bath tube castings, to make a 264-lb. casting requires approximately 18 cwt. of sand for its production, or a ratio of almost eight times as much sand as there is weight of casting, but the new sand required for this job when using a high-grade moulding sand is only about 88 lbs., or less than 1/20th of the total volume of sand to be handled.

Selection of New Sand.

The amount of new sand to be handled is so small compared with the total volume of sand to be handled that in many cases it would not pay to put in any special handling appliances for it, and this factor is still further involved on account of the fact that it is frequently necessary to use two or more grades of new sand to make up a suitable sand mixture, and for this reason a shovel and wheelbarrow may prove to be the cheapest means for handling or transporting sand from the sand bin to the sand mill.

Another factor that enters into this problem is that the sand bins must be of sufficient volume to hold sand enough to carry through periods of bad weather, and hence the supply of sand is not always coming from the same spot in the bin. It is only where very large tonnages are required, and particularly in cases where synthetic sands are used as in the case of the steel casting industry in the United States, that it pays to handle the new or raw sand with grab buckets and special sand-handling appliances. This, however, does not apply to the putting of new sand into storage, for in this case the unit to be handled at any given time is usually at least one carload, and it very frequently pays to introduce special handling equipment, including a bucket elevator, for taking the sand up above the bins, and a suitable belt system for distributing it, and in other cases it pays to use the grab bucket.

In the case of facing sand it frequently pays to put in some handling appliances such as bucket elevators to handle the sand from the mixer to the storage bins, or for the distribution of facing sand to the moulders. Carts or boxes handled on electric trucks or on monorails, or other transportation means are usually the most efficient. There is, however, one fundamental principle that must not be departed from, and that is, that either facing sand or backing sand should, so far as possible, never be carried in a long thin stream after it is properly tempered, for this method of transportation tends to give irregular evaporation of the moisture content of the sand, and results in

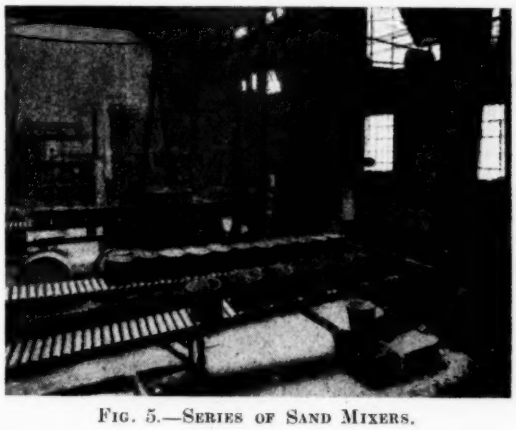


FIG. 5.—SERIES OF SAND MIXERS.

the delivery of improperly tempered material to the moulders, and this frequently cuts down the output of the moulder, and sometimes very greatly increases the scrap.

Handling Backing Sand.

Sand from the shakeout point where it is shaken out of the flasks can be handled on a belt very safely. In many cases, however, it is advisable to shake out into a bin on account of the fact that there is a chance of hot metal falling into the bin with the sand, and if the sand were allowed to fall directly on to a fabric belt the belt would be burned by such metal, but if the time element is introduced by interposing a bin, the sand cools down to such an extent that it will not injure the belt.

The introduction of a belt, however, necessitates the introduction of some form of feeder to take the sand from the bin on to the conveyor belt taking it to the mixing department. For this purpose, in most cases, what is known as a *pan* feeder or *pan* conveyor has been found to give excellent results. This feeder, however, must have slow-moving parts, and must depend on obtaining its volume by having the equipment of ample proportions. This gives us an opportunity for another factor, which is advantageous in the handling of sand, and that is, that any fairly rapidly moving

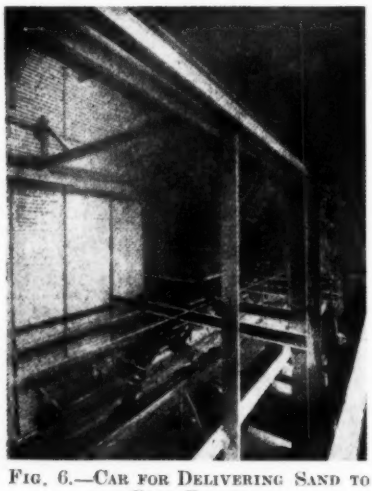


FIG. 6.—CAR FOR DELIVERING SAND TO CORE ROOMS.

feeding device must of its nature be rather small on account of the fact that it would pass a large volume of sand through it in a comparatively short time, and the reduction in size of the feeding devices may give it a tendency to dig in under the sand, which would cause the sand to arch over, but the pan feeder can be made of sufficient area so that the sand can always be free to flow down upon it. By properly designing the bins and proportioning the sand feeder it is possible to install a device which works very satisfactorily and requires little or no poking to make the sand feed. One peculiarity of the pan feeder is that it takes its sand from the back of the bin and passes it under the sand in the bin in the form of a prism, having a cross section equal to the area of the outlet of the pan feeder, and this causes the sand at the back of the bin to cave down and serves to blend the material more thoroughly than it would be by any other form of feeding device with which we are familiar.

After the sand has been shaken away from the castings and transported to the mixing department by means of a belt, or in the case of a very large volume by grab buckets, it must then be put through a series of machines as referred to in the previous part of this Paper, which will incorporate a sufficient amount of new sand, and any other ingredients required such as sea coal, and will rub these ingredients together thoroughly so as to get the sand in the best possible condition, and then the sand must be aerated or opened up by means of some form of beater or agitator, such as the centrifugal mixers. Usually this mixed sand is passed into a bin of considerable capacity and from this it is fed out by means of a pan feeder. The sand falling from the end of the pan feeder is in some cases taken on a belt and distributed to the moulding machines or the bins at the moulding machines. The writer does not favour this method on account of the fact that distributing sand along a long belt exposes it to evaporation, and is liable to deliver it in a relatively bad condition. Also the action of the belt has a tendency to cause the sand to pack and in some cases to form balls. For this reason it seems best to deliver the sand from the pan feeder to the bins over the moulders in some form of cart, car, or buggy, or in a bucket transported on a suitable monorail or crane. This method of transportation exposes a minimum amount of surface to evaporation and causes the sand to arrive at its destination in the best physical condition.

The method of delivering sand to the moulder himself is also of importance. Many foundries have been equipped with bins having different forms of gates for dropping the sand into the mould. A careful series of studies has shown that such gates have a number of inherent faults or difficulties connected with their operation. In the first place, moulding sand from its nature must be a body which will adhere, and this causes it to pack in the gate so that it drops in relatively large bodies and hence it is impossible to get an accurate measure of the sand into the mould, with the result that the moulder frequently has to strike off a considerable amount of sand, and subsequently to shovel it back from the floor. Time study in a number of shops has indicated that if a moulder has to shovel the sand from the floor into a mould on a machine he will get a certain output. If he drops it from a gate overhead this output will be increased from 6 to 8 per cent., but if he shovels the sand from a bin having an opening at approximately knee height his output will be increased about 20 per cent. This is particularly true in the case of moulds containing 44 to 88 lbs. of sand. In the case of very large moulds a gate with a proper chute may be used, or the sand may be introduced by the use of a grab bucket, but this is only practical in the case of very large jar ram moulds or moulds in which the sand is packed by some mechanical means after the proper volume is in place.

What has been said in regard to the handling of moulding sand is to a large extent also applicable to the handling of core sand, but in the case of oil sand cores or cores in which the entire mass of sand is thrown away after being used once the volume may be so great that it pays to put in some form of sand handling equipment to bring the new sand from the sand storage to the sand-mixing plant.

Equipment Used in the States.

A few illustrations showing various devices used for handling sand may be of interest. Fig. 1 shows a grab bucket on a monorail which is used for taking sand from under the shakeout in a foundry and transferring it to the mixing equipment. Where the output is large enough this method has been found very economical, and it is also very advantageous on account of the fact that the grab bucket handling action itself gives a certain amount of mixing to the sand. Fig. 2 shows a sand hopper with a platform at the bottom and

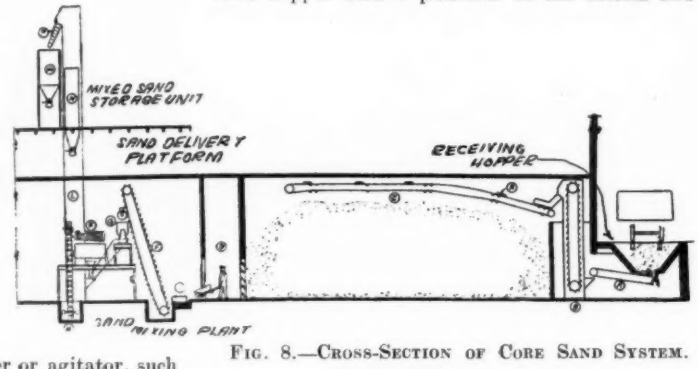


FIG. 8.—CROSS-SECTION OF CORE SAND SYSTEM.

the top so arranged that sand can be dropped into the top of it from buckets carried on a monorail, and can be shovelled from the bottom to the moulders. Fig. 3 is a front view of a series of these bins in operation, and in this illustration a bin has been placed next to each moulding machine. A considerable number of plants have been equipped with these bins, which are commonly known as shovel-out bins. In a number of cases, however, it has been found more economical to introduce the sand into the bin by means of a truck on a plat-

form rather than to use a monorail. The reason for this is on account of the difficulty of filling the monorail buckets themselves.

A general view of the end of a pan feeder which is used to discharge sand from the bottom of a large concrete bin into the boot of a bucket elevator is shown in Fig. 4. This particular device has been in use for a good many years, and shows no appreciable wear or depreciation from its constant use, and though the bin under which this pan feeder is placed contains approximately 180 tons of sand it only requires 3-h.p. to operate the feeder.

Sometimes relatively simple devices are used for handling material, and this is well illustrated in Fig. 5. In this case a series of sand mixers is employed for making mixtures of core sand for an aluminium foundry. The mix consisted of two grades of new sand and a certain amount of old sand, and this was bonded with resin and flour. The gravity or roller carriers shown in this illustration were used to assemble a number of buckets of sand upon. As soon as one batch had been discharged from the machine the operator immediately dumped in the buckets, one after another, and

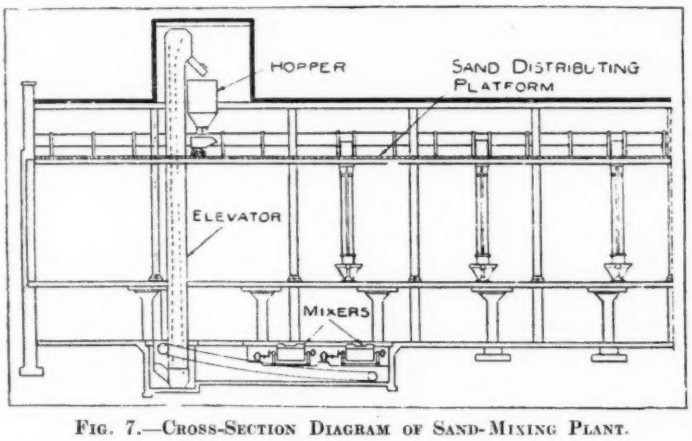


FIG. 7.—CROSS-SECTION DIAGRAM OF SAND-MIXING PLANT.

the angle of approach of the loaded buckets was such that the buckets fed down to him as he required them. The empty buckets would then be pushed back on the other conveyor and filled on the opposite end of the line. On the floor can be seen a bucket into which had been measured up the proper amount of binder and this had been dumped in as soon as all of the sand was in the machine. As soon as the sand was mixed, the proper amount of moisture having been added during the mixing, a gate in the bottom of the machine was opened and the sand discharged into the bucket elevator seen behind the machine. This bucket elevator discharged the sand into a series of bins overhead, and under these bins there ran a small electrically operated car with a dump bottom which is shown in Fig. 6. This car served to deliver the sand to the bins in the various core rooms.

A cross section diagram of another sand-mixing plant is shown in Fig. 7. In this case, in the basement there were two sand mixers which discharged on to a belt that in turn delivered sand to a bucket elevator that carried it to a hopper overhead, and from this hopper it was drawn into a small dump truck, which was pushed along the sand delivery platform, and the sand was dumped down chutes into the centre of the core makers' benches. Only a portion of the line of core makers' benches is shown in this illustration.

A cross section of another core sand system is shown in Fig. 8, and this consists of a series of track hoppers under the railroad track from which the sand was fed by pan conveyor " A " to bucket elevator " B." This bucket elevator delivers the sand on to a conveyor belt " C," which has scrapers at suitable intervals as indicated by letter " R." These scrapers serve to deposit the sand into storage. There is a passage " D " which leads along the face of the sand bins, and the sand is wheeled to the hopper " E " in which the proper amount of the various ingredients are introduced. This material is then fed by means of a screw to the belt " F," which delivered it to the mixer " G,," and after mixing it is discharged into bucket elevator " L " and delivered through the spout " P " to the bin " M." The same spout also serves to deliver sand to other bins " N " located at the sides of the elevator. There are three bins in the series indicated at " M " which served to furnish sand for the sand delivery platform over the core makers' benches, while the lower bins " N " delivered sand to carts which take the sand to the core makers who worked on the floor.

A general view of the core-makers' benches and the sand delivery platform is shown in Fig. 9.

We might multiply examples of sand-mixing equipment, but the writer believes that the examples given show some methods for solving problems which are applicable to a wide variety of cases. Particular attention, however, is called to the fact that sand for different types of castings frequently has to be treated in a different manner, and that a system of handling applicable to one foundry might not be at all applicable to another. Every problem has to be studied on its own merits, and frequently it is impossible to show a substantial profit by the introduction of certain types of equipment, and in such cases the only thing that can be done is to introduce devices which will reduce the manual labour without unnecessarily increasing the amount of mechanical equipment involved. Frequently a careful study of the method of sand delivery and the types of carts or buckets used will result in a saving.

In connection with French foundries the writer believes that in most cases the greatest saving can be made by studying out an economical method of delivering sand into the bins adjoining the moulders, and at the same time to provide a method of getting the sand from the shakeout back to the sand-mixing equipment. When backing sand is mixed by shovelling we are employing a very expensive medium, and in foundries in which it is hard to get labour it is very important to do away with unnecessary manual work and to free these men for productive labour in other lines. It is a careful study of problems of this kind which

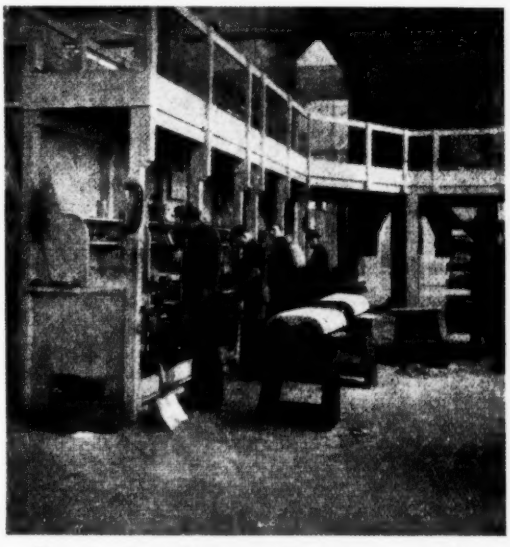


FIG. 9.—SAND DELIVERY PLATFORM OVER CORE-MAKERS' BENCHES.

will result in much saving in foundries. In some cases, and particularly in non-ferrous alloy shops, it has been found that a sand handling plant could be made to show an excellent profit even though the volume of material handled was relatively small.

Cast Iron and Mass Effect.*

By O. SMALLEY, M.A.I.M.E.

The information available regarding the chemical and physical phenomena occurring in cast iron as affected by rate of cooling is meagre and sparse. It is well-known, however, that large castings present many difficulties which do not exist in small castings and demand greater individual skill and experience. It is also known that the molecular changes of grey iron on solidification are both complex and uncertain; and that

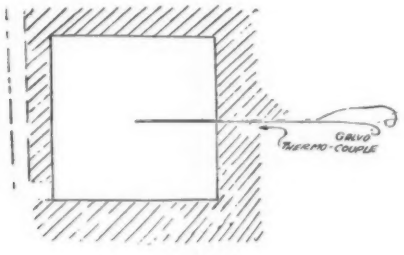


FIG. 1.

the properties of casting will be determined by their nature and magnitude, *i.e.*, the strength and solidity bear some relation to the time and temperature of the metal solidifying in the mould.

The author is not cognisant of any attempt at systematic investigation of the mass problem. It assumes proportions of huge dimension, and presents a fertile field for research to which the contributed co-operative effort of many investigators is necessary to its scientific understanding.

This Paper, then, does no more than present the subject as a whole for discussion, and indicates the mode of attack made by the author.

Technically, the laws involved in this study are those of mass action and heat transfer. The law of mass action indicates when and in what direction an equilibrium will be changed by an increase of concentration, *i.e.*, a pressure of any one component of a chemical reaction. The complexities for this with regard to cast iron are only too well known. The law of heat transfer is even more involved. The governing factors in the transfer of heat between the fluid metal and the mould which affect the solidity of a casting are:—(1) The degree of superheat in the metal; (2) its latent heat value; (3) volume changes on solidification; (4) dimension and form of the casting; (5) initial temperature of the mould; (6) heat conductivity of the material from which the mould is made; (7) heat capacity of the mould.

Factors not easily represented by a single term, and which will always render the law of relation between mass and the physical properties difficult of mathematical expression.

Such variables make it impossible to consider the laws to any length in our present state of knowledge of the subject, and the author but essays to project the more salient practical aspects of the mass problem which are of immediate importance to both engineer and foundryman, viz.:

(1) The time factor for various sections of cast iron to solidify under known conditions.

(2) The effect of chemical composition on the solidity penetrating power of grey cast iron.

(3) The relation between the chemical and structural changes as effected by time and temperature, *i.e.*, to correlate texture with rate of cooling and discuss the means permitted in the control of the same.

(4) To consider briefly the adoption of some simple standard of solidity and to proceed from this to discuss the effect of design on the strength in normal castings.

(5) The rate of running to the mass effect, and to discuss its possibilities and limitations in its application of the manufacture of solid castings without risers.

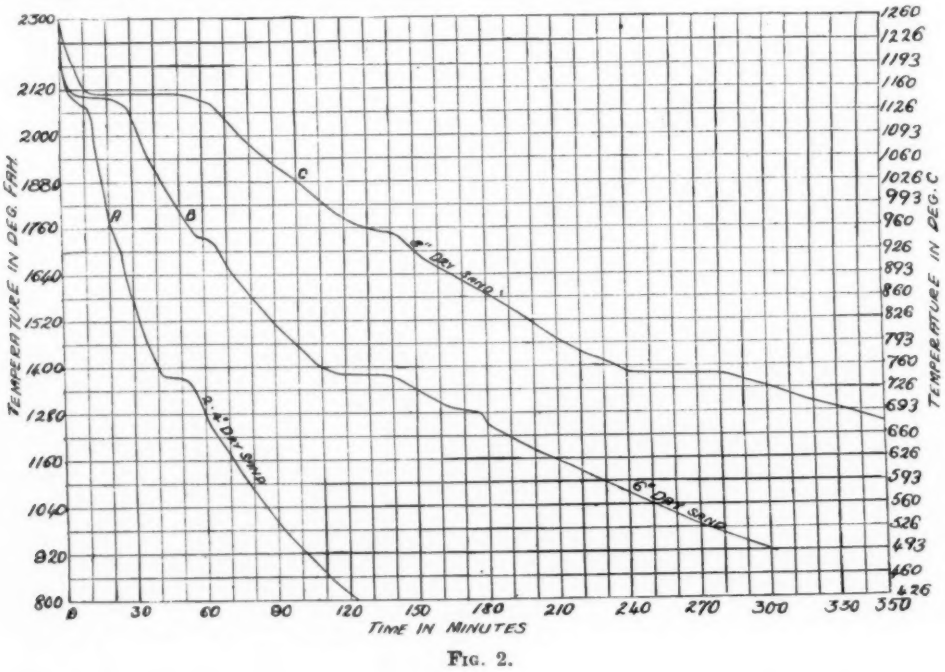


FIG. 2.

Time Factor of Various Sections of Cast Iron to Solidify under Known Conditions.

At the present outset let the object of this investigation be clearly understood. It is to ascertain the time taken for various sections of cast iron to solidify under known conditions. For purposes of comparative data, as many variables as possible have been eliminated, excepting the one under consideration. As it was essential to obtain some degree of accuracy, laboratory conditions were reproduced as closely as possible. The section chosen was the ordinary square commencing with 2, 4, 6 and 8 ins. respectively. The moulds were made in dry sand consisting of:

* A Paper presented to the Paris Foundry Congress on behalf of the Institute of British Foundrymen.

—12 parts of floor sand, 8 parts of Erith loam, and 2 parts of sawdust.

These were baked at 400 deg. Fah. and allowed to cool to 100 deg. Fah. for castings. Each mould was made under similar conditions and well vented. A Pt.—Pt.-Rh. thermo-couple was placed in the mould as shown by Fig. 1 and cast in the centre of the block so that the recorded time temperature figures would represent the conditions operating in the mould from incipient solidification to room temperature. The thermo-couples were made from the same batch of wire and calibrated to a standard instrument to an accurate of plus or minus 2 deg. at 1,300 deg. C.

The thermo-junctions were protected by means of a fine silica tube fastened in the mould.

The metal was melted in an 8-ton cupola using a mixture consisting of:—

4 cwts. East Coast hematite mixed numbers, 6 cwts. Cleveland, and 10 cwts. machinery scrap, calculated to yield the following intended composition:—T C, 3.2 to 3.5; Si, 2.0; Mn, 0.7; P, 0.9; and S, 0.06 per cent.

The temperature of the metal on leaving the cupola was 1,380 deg. C. This was run into a 1-ton ladle and each casting poured at approximately 1,315 deg. C., each block was run quickly from the bottom, the area of the ingate being adjusted so that the time to fill each mould would be approximately similar.

Time readings were commenced from the maximum temperature recorded by the pyrometer, measuring the time for every 20 deg. Fah. fall.

Curves A, B, and C, Fig. 2, represent the time temperature curves obtained from these blocks. Details of the relative time occupied in the solidification of each are given below:—

2.4-IN. BLOCK

Temperature range	Time in minutes
Main solidification: 2,130 to 2,078 deg. F.	10 min. 35 sec.
Incipient solidification to Phosphide Eutectoid. 2,130 to 1,715 deg. F.	23 min. 15 sec.

6-IN. BLOCK

Temperature range	Time in minutes
Main solidification: 2,160 to 2,060 deg. F.	28 min. 42 sec.
Incipient solidification to Phosphide Eutectoid. 2,160 to 1,715 deg. F.	66 min. 5 sec.

8-IN. BLOCK

Temperature range	Time in minutes
Main solidification: 2,180 to 2,060 deg. F.	63
Incipient solidification to Phosphide Eutectoid. 2,180 to 1,715 deg. F.	145

It will be observed that the time occupied during solidification of large masses of iron may reach alarming figures and that, even for ordinary castings, the principal operative forces in the mould responsible for the commoner metallurgical defects, viz.:—

(1) Volume changes on solidification, expansion or contraction; (2) crystallisation; and (3) liquation, have ample opportunity for manifestation.

Etchings 1, 2 and 3, Fig. 3, taken from each cube after sectioning through the centre vertically, show the result of these forces on the solidity and texture. They are self-explanatory of the effect of the mass, and both the 6-in. and the 8-in. show that, despite the complete filling of the mould under pressure with an iron which expands on solidification, the long range of temperature through which it solidifies, and the high conservation of heat in the centre, due to slow cooling, result in a defect of appreciable dimension, and considerably more extensive than would be encountered in a freely-contracting iron.

Chemical Composition and Mass Effect.

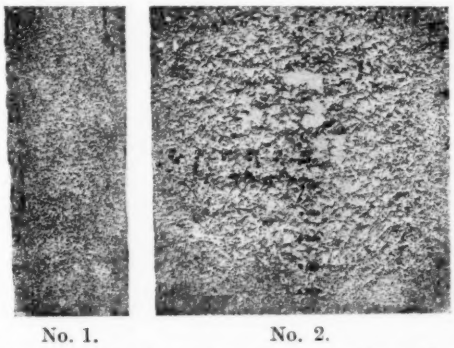
To illustrate the part played by chemical composition on mass effect as far as "Solidity" is concerned, a set of 6-in. cubes were cast in dry sand moulds from the bottom, poured at the same rate and under similar conditions as far as was practicable. The temperature of each mould on casting was controlled between 100 to 110 deg. F.

The series of irons to be considered here are a high Si, high P, a low Si, high P, and a low Si low P. The chemical composition of these are given below:—

	TC	Si	Mn	P	S
1	3.12	2.49	0.52	1.28	0.050
2	3.27	1.15	0.62	1.54	0.086
3	3.40	1.20	0.63	0.09	0.063

Each was melted in an 8-ton cupola and poured with 10 per cent. superheat.

Etchings 1, 2 and 3 Fig. 4 taken from each cube after sectioning vertically through the middle, clearly illustrate the relation between



No. 1. No. 2.

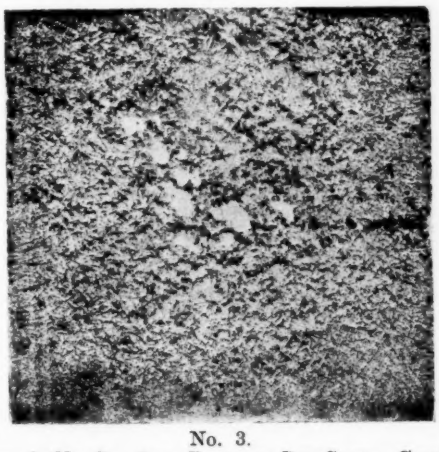
FIG. 3 (No. 1).—2.4-IN. BLOCK OF DRY SAND. CHEMICAL COMPOSITION: TC, 3.19; Si, 1.97; Mn, 0.62; P, 0.87; S, 0.068.

FIG. 3 (No. 2).—6-IN. BLOCK OF DRY SAND. CHEMICAL COMPOSITION: TC, 3.24; Si, 2.04; Mn, 0.57; P, 0.85; S, 0.065.

chemical composition and mass, as far as solidity is concerned. They also give some idea of the adjustment possible by chemical control in ordinary cupola practice. It will be observed that iron No. 3 containing 1.20 per cent. Si and 0.09 per cent. P is equally solid throughout.

Special Elements.

Where adjustments of the ordinary chemical elements, viz., C, Si, Mn, P and S are limited, the degree of *solidity penetrating power* may be increased by the introduction of special metals such as Cu, Ni, Cr, Mo, and W. To illustrate



No. 3.

FIG. 3 (No. 3).—8-IN. BLOCK OF DRY SAND. CHEMICAL COMPOSITION: TC, 3.01; Si, 1.92; Mn, 0.52; P, 0.86; S, 0.076.

this point in a more practical way, a series of castings of T section were made. When cast in an ordinary soft grey iron, this section invariably exhibits an open texture in the centre of the heavy section, portrayed by etching No. 1, Fig. 5.

Etchings 2 and 3 in this figure illustrate the effect of 49 per cent. Ni and 45 per cent. Cr, respectively.

These show that both Ni and Cr, not only eliminate the draw at the heavy section, but have resulted in a uniform grain throughout. The relative "solidity penetrating power" of the two elements may be gleaned from the Brinell figures.

Rate of Cooling and Solidity.

In a previous research on this subject, the author has been able to show that cupola-melted grey cast iron of normal chemical composition does not draw on solidification if poured with a sufficient degree of superheat and if cooled faster than a certain critical rate, or in other words, there exists for each grade of cast iron a minimum

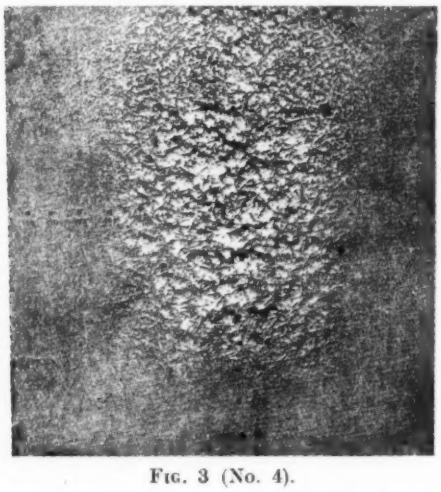


FIG. 3 (No. 4).

rate of cooling during solidification which yields, within practical limits, the same grain or density, regardless of section or dimension of the casting when poured with a suitable degree of superheat. What this permitted minimum critical rate of cooling and range of superheat are, still await scientific determination, whilst the explanation of the chemico-physical reactions involved is still a matter of conjecture.

This investigation, once systematically conducted, would provide information such as would permit both the engineer and foundryman to specify the grade of iron and the method of construction of the mould, such as would ensure the strength and solidity throughout all sections of any casting. It is one of the important researches confronting the Cast Iron Research Association, and until such data is forthcoming, the engineer is in the hands of the foundryman, who is restricted by the limitations of his training and past experience.

Mr. Broughall, in his well-known researches on "Denseners" deals with the practical aspect of the question, and shows how, by speeding up solidification of the outer shell of the casting, the natural expansion of the metal is resisted and results in a casting of considerable density.

His theory is that immediately the iron is poured into the chill-mould, considerable and definite expansion of the iron takes place, which, being resisted by the mould, is converted into a compressive force which submits the casting to such a tremendous pressure, that the density of the iron is increased. It has been proved repeatedly that rapid cooling does effect this densening, and the author has already shown that it is possible to make any grey-iron casting sound, provided that the metal is hot enough, and the rate of cooling sufficiently rapid.

The explanation given by Mr. Broughall of the reversal of the expansion forces by the rigidity of the mould, however, remains to be proved, for grey cast iron may be cast in a rigid mould and present both a pipe and internal draw.

The author inclines to the view that the rigidity of the mould does not enter into the question, but that the non-contracting properties and solidity of grey cast iron when poured hot and rapidly cooled are an effect of (1) a time-temperature balance reaction between the constituents present—chiefly carbon— and the dissolved gas, this latter being retained in solution under considerable pressure, and (2) of super-cooling.

To consider this in practice, take the 8 in. cube, comparing one cast in the ordinary dry sand mould, with one cast in exactly the same form of mould, but lined with 1 in. steel plates. Two castings were made from the same melt of iron, poured at the same temperature with the same head and at the same rate.

Thermal Curves.

Cooling curves were taken from each block in the manner previously outlined. A comparison of inverse rate curves 1 and 2, Fig. 6, clearly reveals the surfusion of the chill cast block. The relative *quantity* of heat evolved during incipient, main and phosphide eutectoid solidifications are better shown by curves 1 and 2, Fig. 7.

Etchings 3 and 4, Fig. 3, indicate the relative solidity and texture of each block after sectioning vertically through the middle. The former possesses a large, coarse, weak structure, unsound at the centre to an area of 2 in. The chill cast block has a fine texture and is remarkably solid throughout.

These etchings are self-explanatory of the remarkable grain-refining or densening effect of the surfusion phenomenon of cast iron. Its practical application, however, is not limited to the use of the rigid mould or to iron and steel chills. Surfusion is a physical phenomenon affected by the: (1) Latent heat of fusion values;

No. 1. No. 2. No. 3.

FIG. 4.—CHEMICAL COMPOSITION: No. 1—TC, 3.12; Si, 2.49; Mn, 0.52; P, 1.28; S, 0.50. No. 2—TC, 3.27; Si, 1.15; Mn, 0.62; P, 1.54; S, 0.086. No. 3.—TC, 3.40; Si, 1.20; Mn, 0.63; P, 0.09; S, 0.063.

(2) chemical changes in the molten metal; (3) temperature of melting; and (4) temperature of pouring.

It is to these that the explanation of many of the vagaries of structural variance of cast irons of similar chemical composition and of similar section must be sought. It presents a field of research pregnant with possibilities.

Latent Heat Values During Solidification of Cast Iron.

Fletcher, in a recent paper, states that Si slows down and Mn quickens the rate of solidification. It would be interesting to obtain the composition of the irons used in his investigation. The following figures were obtained by the author from two phosphoric irons containing 1.15 and 2.49 per cent. Si respectively.

T.C.	Si	Mn	P	S	Main solidification °C.	Latent heat of solidification		Phosphide Eutectoid °C	Latent heat of solidification	
						B. T. U.	Gram calories		B. T. U.	Gram calories
3.27	1.15	0.62	1.54	0.086	1125	39	21.7	957	17	9.5
3.12	2.49	0.52	1.28	0.050	1132	40	22.2	960	18	10.0

These indicate that Si is not appreciable in its influence on ordinary cast iron, whilst from an extensive series of cooling curves taken under known conditions, it becomes extremely difficult to give an expression with regard to the true effect of either Si or Mn on this point. Without systematic investigation under standard conditions, considering each of the elements present, one can scarcely draw conclusions on the subject. Similarly the composite whole involves such a labyrinth of data that it is impossible to formulate any definite statements from our present knowledge.

Mons. Ronceray and Signor Brunelli and others have demonstrated the possibilities of slow or jet running as a factor in the production of sound castings. The potential value of this as a means to obviate some of the common defects due to mass effect remains undisputed. The principle of slow running is to obtain simultaneous solidification conditions throughout the casting. It is a factor, however, strictly limited in its practical application, and ceases to be wholly effective as soon as the rate of running permits the natural volume changes of the molten metal on solidification to operate, *i.e.*, as soon as the rate of running exceeds the time taken to solidify. The limitations of this principle in its practical application are only too obvious where mass influence is to be contended with.

Take, for example, the 8-in. cube sand cast. The time figures for solidification of this mass of metal are as follows:—

Sixty-three min. from incipient to main solidification and 82 min. from main solidification to the complete solidification of the phosphide eutectoid, *i.e.*, a total time from incipient to complete solidification of no less than 145 min., 2 hrs. 25 min. From Curve I. (Fig. 6) it will be observed that incipient solidification of the silico-ferrite commenced at 2,180 deg. Fah., the main solidification at 2,110 deg. Fah., and the block retained this latter temperature for no less than 44 min. 32 sec. The time for the development of the primary crystal grains thus occupied altogether 63 min., whilst the phosphide, remaining molten for a further 82 min., afforded ample opportunity for liquation and segregation.

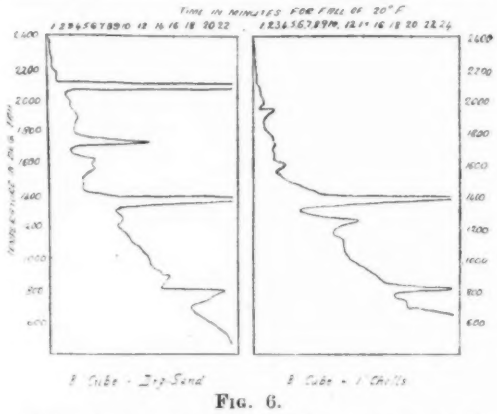


FIG. 6.

To run such a casting sufficiently slowly to eliminate ill effects of the natural volume changes, crystallisation and liquation effects of the solidifying metal without speeding up the rate of solidification, thus becomes impossible.

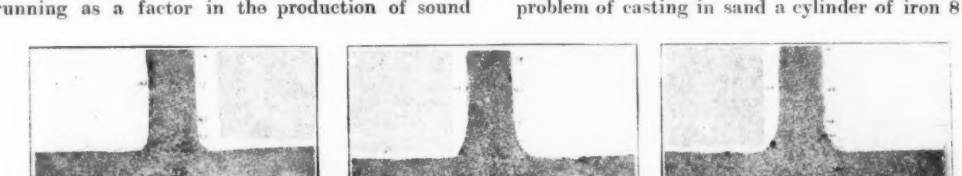
It amply shows, however, that to take full advantage of the factor of "rate of running" so far as the manufacture of uniformly solid castings without risers is concerned, it must be considered in conjunction with the time taken during solidification, *i.e.*, one must adjust the rate of running by the method of moulding, temperature of pouring and the chemical composition.

To illustrate this in a more practical way in regard to its relation to mass effect, consider the problem of casting in sand a cylinder of iron 8 in. dia. and 12 in. long, uniformly solid in ordinary cylinder iron. A casting of simple form, yet because of its dimensions, presents peculiar difficulties. On first thoughts, it might be contended that such a cylinder need only be run sufficiently slowly to feed out the draw, or that a sound casting would be obtained by the aid of 4 to 6 in. of head and a feeding rod.

To exemplify this, two cylinders were made, the one without any head and running centrally from the top by means of the finest possible jet, the other with 4 in. of head and feeding carefully with a rod. After a series of preliminary experiments, it was found that such a block could, under special conditions, be run by means of a ¼-in. dia. jet, if a large runner basin, which has been preheated to 300 deg. C., were used. (Fig. 8) shows the method of running and form of runner basin. The mould temperature was controlled at 100 deg. Fah. The metal used was of the following chemical composition: TC, 3.21; Si, 1.60; Mn, 0.62; P, 0.77; and S, 0.036 per cent., and was poured with 10 per cent. superheat.

The conditions thus obtained therefore were such that, as far as slow running was concerned, the extreme was taken. Incidentally, this experiment offered interesting information regarding the filtering possibilities of small jets.

On removing from the mould, the casting presented a perfectly smooth and clean skin. It was sound and free from blow holes or other defects. There was no evidence of either piping or sinking and it would have machined clean on all faces with a light cut. (Fig. 9) represents a sulphur etching taken through the centre of the finished casting. The coarsening of the texture from the outer walls to the centre by the slow rate of cooling due to mass is clearly revealed. At a position approximately ⅓ the length of the casting centrally from the top, extending to about 44 sq. in., is the internal draw, the enigma and Nemesis of cast iron of any dimension, although the upper 4 in. of the casting is quite sound. On sectioning the



No. 1.—CHROMIUM. No. 2.—ORDINARY. No. 3.—NICKEL.

FIG. 5.—CHEMICAL COMPOSITION: No. 1—TC, 3.41; Si, 2.28; Mn, 0.61; P, 0.87; S, 0.087; Cr, 0.45. No. 2—TC, 3.16; Mn, 0.64; S, 0.093; Si, 2.24; P, 0.88. No. 3—TC, 3.28; Mn, 2.18; S, 0.078; Si, 2.18; P, 0.92; Ni, 0.49.

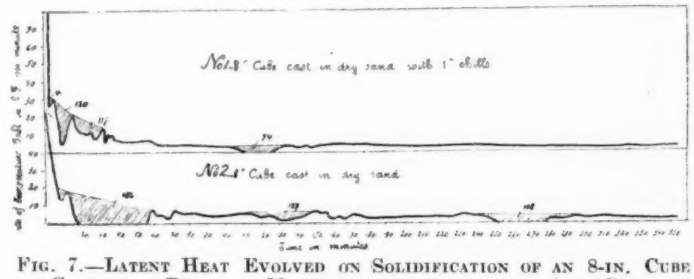


FIG. 7.—LATENT HEAT EVOLVED ON SOLIDIFICATION OF AN 8-IN. CUBE CAST IN A DRY-SAND MOULD WITH AND WITHOUT A 1-IN. CHILL.

block cast with 4-in. head, which had been fed with hot metal, the same defect was encountered.

This simple illustration suffices to demonstrate the difference between the elementary problem of feeding-out of the pipe in an ingot of a contracting metal such as brass or steel, which freeze through a short range of temperature, by slow pouring and the complex problem of preventing

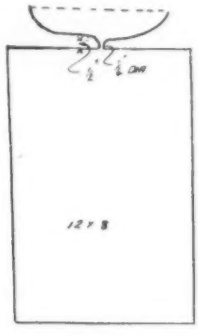


FIG. 8.

drawing of grey cast iron, a material which expands on solidification and freezes through a wide range of temperature.

Some idea of the length of time the metal remained molten after filling, despite the slow rate of running, is evidenced by the rising of the sulphur compounds to the top of the cast, as shown by the sulphur print; although the sulphur in the

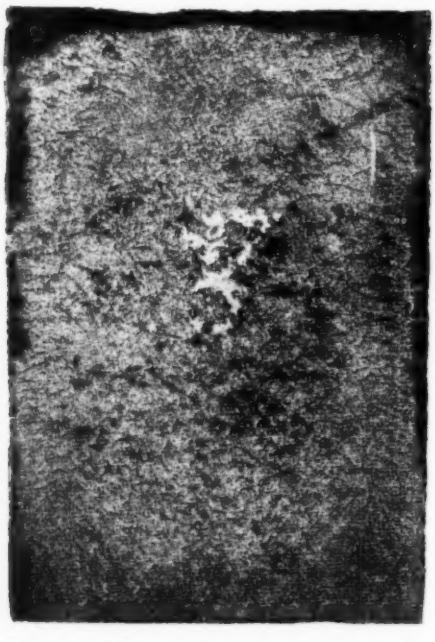


FIG. 9.—CHEMICAL COMPOSITION: TC, 3.21; Si, 1.60; Mn, 0.62; P, 0.77; S, 0.036.

iron used was comparatively low, 0.05 per cent. The upper ¼-in. of the cast was found to contain 0.37 per cent. S.

Filtering of Cast Iron.

From time to time the author has had various methods of "filtering" cast iron submitted to him. The process of these methods was never made quite clear, but as far as could be gathered, the inventors claimed to remove certain objectionable impurities from the iron and to ensure clean and dense castings. Such devices as strainer cores, jet and slit runners, etc., undeniably justify their adoption. These methods, however, always necessitate the use of hot metal, the first essential to clean, sound and dense castings, and safeguard against careless skimming. (Fig. 9) shows that the metal is not purified by the so-called filtering process. It is a misnomer, calculated to mislead, rather than enlighten, and it is for this reason that reference has been made to it.

Conclusion.

This introductory paper has but touched the fringe of the mass problem. The controlling influences in the manufacture of solid castings, viz.: (1) Time factor during solidification; (2) temperature of pouring; (3) chemical composition; (4) rate of cooling; and (5) rate of pouring, have cursorily been surveyed and practical illustrations chosen to demonstrate the relative importance of each factor involved. Where possible, every endeavour has been made to eliminate all variables except the one under consideration. This method has obvious disadvantages to the more practical foundryman, who, thinking in terms of a finished casting, is often too bewildered by the numerous variables involved in his art to reason by a process of elimination. It is, however, only by consideration of one variable at a time that a bedrock foundation can be laid from which scientific principles involved may be estimated.

Cupola Reactions.*

BY COLONEL JAIME COLL, M.I.Brit.F.

The reading of the various matters on cupola melting facts leaves the average foundryman somewhat bewildered. Recalling on the one hand that conflicting opinions obtained on the points of view upon superheating were upheld by Mr. Elliot in his Exchange Paper, discussed at the Blackpool Conference, on the other hand, if we note the different positions recommended for the steel in semi-steel charges, it will be very obvious that the most competent foundrymen are at a loss respecting what takes place in the cupola.

But notwithstanding, it seems at first sight that with the data already possessed, referring to facts in which theory and experience coincide, it would suffice to find a few missing links in order to avoid notable discrepancies in the appreciation of melting problems.

It is not maintained that it is an easy task to clear up this matter, but the author states that the repetition of Belden's experiences† with the cupola charged as in ordinary practice (not with coke alone) should perhaps begin to diffuse light.

In fact, Mr. Felton‡ theorising on cupola reactions and Mr. Grennan§ conducting valuable practical observations at the Michigan University have already gone along a path which may lead to some satisfactory explanations, especially if the metallographists, on their side, can exactly determine when, where, and how the transformation or solution of the graphite in the matrix, within which it is mechanically mixed, takes place in the cupola.

When this goal is reached, the three works alluded to, together with the results of other experiments, allow one to explain tentatively some current facts and to point out the main lines of research to be followed.

Efficiency of Moistening the Coke is not Clear.

Taking as granted the accuracy of the temperatures measured by Mr. Grennan, corroborated to some extent by his visual observation of the melting progress, it appears firstly as very debatable the efficiency of moistening the coke—as practised by Mr. Riddell—in order to delay the increase of combined carbon in the descending metal, because with temperatures over 800 deg. C., 6 ft. above the tuyeres, there should not remain the least trace of moisture. There must be, however, something—not yet explained—in it, when Mons. Ronceray‖ also affirms to have found advantages in this practice.

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* A Paper read before the Paris Conference.

† U.S.A. Bureau of Mines, Bulletin 54. "Foundry-Cupola Gases and Temperatures."

‡ "The Foundry," May 1, 1923.

§ Visual observation of melting in a cupola. Paper read at the Cleveland Convention, 1923.

‖ "Données pratiques sur la conduite du cubilot." La Fonderie Moderne. March, 1923.

Position of Steel in Semi-Steel Charges.

Coming now to semi-steel charges, it is logical to admit that very near the charging door there exist temperatures of 900 deg. C., sufficiently high for the steel to begin dissolving carbon gradually, lowering in this manner its melting point. As the steel takes the carbon from the gas and the incandescent coke, it seems that the most convenient places for it must be on the top of the coke or immediately underneath it. It will be well, therefore, to discard the intermediate position sometimes advised, because, although when approaching the hottest zone it is probable that all the materials of every charge mingle with each other, the temperatures over 900 deg. C. extend to so near the charging door that if the cupola be well charged it should not be presumed that the mingling has begun there.

Does Steel Melt Partly as Such in the Cupola?

However, in this first stage, the carburisation is not likely to be great because in the vicinity of the critical point Ac. 3 an extended action is necessary in order that the absorption of carbon should become remarkable, as has been proved by Mr. Cameron's experiences.* According to these experiences, on the bars being withdrawn from the cupola a few moments before melting, the absorbed carbon hardly reached 0.65 per cent. On the other hand, the cementations cited by Mr. Fletcher† require several hours of contact to be accomplished.

Of course, the carbon absorbed by the iron bars of Mr. Cameron's experiences might not have been uniformly distributed through the whole cross-section of the bars whilst inside the cupola; its percentage might have been higher at the surface than in the heart, but the prevailing temperatures, as ascertained in Mr. Grennan's cupola (over 1,500 deg. C. in hole No. 1‡ and averaging 1,450 deg. C. in hole No. 2§ incline to admit, against the current belief, that steel melts partly as such (with scanty supplementary carburisation), afterwards increasing its carbon content by contact by reason of it falling with the incandescent coke through which they must pass until the crucible is reached, without taking into account the diffusion which may or may not be produced when the scrap melting above drips on to the steel about to melt. Although the observations of Mr. Grennan confirm that not only the scrap of each charge, but also that of the two consecutive charges, can by its simultaneous melting produce this washing effect, it is difficult to admit that every point of the steel pieces is reached by the drip of the scrap from above.

To further support the hypothesis that, partly at least, the steel is able to melt as such in the cupola, the author points to the case in which, by using lengths of medium heavy rails (30 to 40 kgs. per linear metre), the carburisation and subsequent melting of the successive outer surfaces are not so quick as the descent of the charges; the remaining steel body must therefore arrive at the hottest zone without sufficient carbon absorption. Prevailing there temperatures over 1,500 deg. C., and even over 1,600 (without applying to the 2,200 deg. C. admitted by Mr. Elliot and Dr. Moldenke), there is no reason why such a body should not melt then and there. The author uses often this class of steel scrap, and experienced no troubles due to oxidation, which seems to prove that melting is ended before reaching the free-oxygen zone.

Also, it is not probable that under these conditions the steel should melt before the pig-iron. Mr. Cameron's experience on Armistice Day and Prof. Campion's affirmation‖ about steel melting were very likely founded because the use of thin pieces which, with light mass, will offer a great surface of contact to the coke and gas.

Tentative Explanation of Graphitic Iron Melting.

Some phenomena of pig-iron melting, however, by far older than steel melting in the cupola, are more difficult to guess at, Dr. Moldenke† refers to highly interesting experiences carried out in an open-hearth furnace with metals of identical integral analysis, but of "dead-white" and "dead-grey" fracture respectively. Although the atmosphere is not of the same nature in the open-hearth as in the cupola, the difference noted about the manner in which melting took place in both cases teaches its lesson, being only regrettable that Dr. Moldenke should have omitted to give in his magistral text-book the temperatures and the percentages of elements besides carbon in the tested metal.

We only know that the "dead-white" was chill-cast (high in combined carbon), while the "dead-grey" was sand-cast (high in graphite).

The difference of behaviour in melting confirms the current opinion: Whilst the hard iron melts by the simple phenomenon of taking in the necessary heat, the soft iron needs a previous transformation which can only refer to the solution of graphitic carbon in the impure steel matrix surrounding it.

It would be very useful to know the melting point of this matrix (it must be surely low in combined carbon) and its variations for different contents of the other remaining elements always found in cast iron, but it is more urgent to determine as accurately as possible the temperature at which the graphite begins to change into cementite, if there is not another intermediate state not yet defined.

The author has wondered whether the catalytic action of CO and CO_2 forwarded by Prof. Kôtarô Honda‡ might contribute—supposing it were reversible—to explain the solution of graphite in iron, but there seem to be a lot of difficulties when trying to couple this still uncertain theory to the melting of dead-grey iron in the cupola.

The phenomenon observed by Dr. Moldenke of the whole mass becoming suddenly liquid after its softening and flattening might perhaps furnish an explanation founded on the fact that as the throwing out of solution of graphite in cooling gives up heat, its absorption by the impure steel matrix takes in heat while it is completed through the whole mass to such an extent that the prevailing temperature meets the melting point of the newly-formed alloy with the new percentage of combined carbon, when melting takes suddenly place. The previous softening and flattening might then be explained by the molecules drawing together as graphite gradually disappears from the cellules originally filled up by it.

Perhaps this tentative explanation may prove erroneous, but it seems at first sight more accurate than the surmise, widely spread, that the graphite is not absorbed by the matrix until this latter is thoroughly melted; not only because its melting point is necessarily high—as on the contrary it should migrate from the pig-iron like the eutectic phosphide—but also because it is difficult to admit a sudden solution of all the original graphite into the drops which, owing to their greater density, should quickly outrun it in falling.

Research to be Undertaken on Superheating.

Concerning the utility of the cupola for superheating the molten metal originated from chill-cast pig-iron, the author agrees with Mr. Felton that "the greater distance it drops through the hot zones gives it enough superheat to make up for the lower melting point"; but the question is: How is this superheating accomplished? By simple conduction, or by Si and Mn being oxidised below the connected CO_2 zone of Mr. Felton?

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* "Semi-steel." Birmingham Conference, 1922.

† "The Blast Furnace and the Foundry Cupola." Appendix. FOUNDRY TRADE JOURNAL, 13-IV.-1923.

‡ 21 in. above the tuyeres.

§ 27 in. above the tuyeres.

‖ Discussion of Mr. Cameron's Paper on Semi-steel.

† "Principles of Iron Founding," page 99.

‡ "On the constitutional diagram of the iron-carbon system based on recent investigations," Journal of the Iron and Steel Institute. 1922-No. 1.

REAR-ADMIRAL SIR GODFREY M. PAINE, K.C.B., M.V.O., who was Fifth Sea Lord of the Admiralty and Air Vice-Marshal during the war, has been elected chairman of the Wellman Smith Owen Engineering Corporation, Limited, of London and Darlaston.

Graphitisation in Cast Iron.*

By E. Adamson (Sheffield).

(Slightly abridged.)

From published works which the author has been able to peruse it would appear to have been taken for granted that the graphitisation of cast iron is a function of slow cooling or of heat treatment, i.e., annealing. No notice whatever appears to have been taken by investigators of the original temperature to which the iron was raised during the operation of smelting, or of the length of time the metal remains in the molten state, whether this is inside the blast furnace before tapping or in the foundry ladle afterwards.

It is therefore proposed to treat graphitisation in its widest sense, i.e.:—(a) Annealing; (b) slow cooling; (c) when cast iron is molten; (d) due to primary temperatures during the process of smelting; (e) due to the *growth* of graphite after its formation.

In all these operations *time*, as well as *temperature*, must be considered, as it is these two factors which have such a very great influence on graphite and its condition.

It is perhaps fitting that this paper should be given in Paris because the research work of three Frenchmen has a most important bearing on the subject. Charpy and Grenet in 1902 published a most significant research in the Bulletin de la Société d'Encouragement l'Industrie Nationale, on the equilibrium of iron-carbon systems, which has a direct application to graphitisation, although the work of these investigators was intended to show the influence of varying factors on equilibrium. Moissan also, whose work "Le Four Electrique," detailed his investigations on the influence of temperature in the electric furnace on carbon. This work, whilst little understood, even when the English edition was published in 1904, is destined to be an historic treatise on carbon and its connection with metals, including iron, and it is hoped to show in this paper the usefulness of the work of these several investigators, although they did not realise at the time the extent of the value of their researches to cast iron.

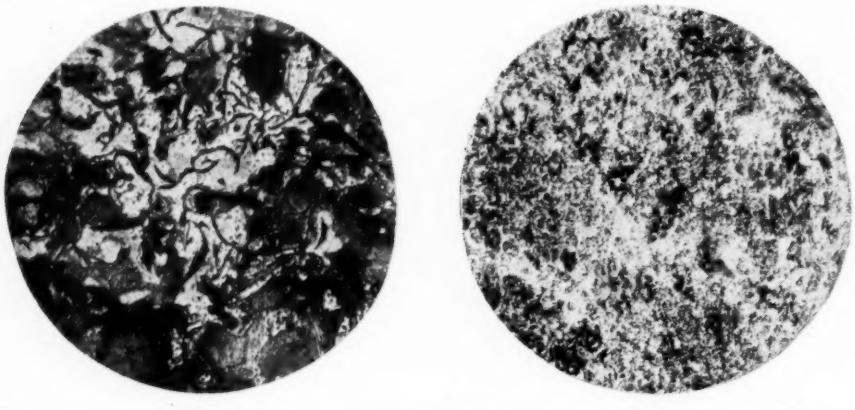

FIG. 1.—SHOWING DIFFERENCE IN GRAPHITE APPEARANCE AT 200 DIAS. WITH CONSTANT CARBON CONTENT.

Annealing.

Although for the purpose of rapid machining it is a common practice to anneal grey cast iron, the word annealing is perhaps best known as applied to malleable cast iron, which must be of a white fracture (all combined carbon) before the operation of annealing is commenced. This white fracture with a suitable silicon, sulphur and manganese, when annealed for several days at a temperature of about 700 deg. C., produces—commonly known as precipitating—very finely divided graphite, to which Ledebur has given the name "*amorphous carbon*," and this type of free carbon is also known as "*annealing carbon*." When the annealing at this temperature has been completed the fracture has a very black appearance, suggesting lamp-black, and this form when in malleable cast iron is known as "Blackheart," or American practice, which is quite different in colour and even size of free carbon from the ordinary fine grey fracture of a very close grained pig-iron.

When, however, the temperature of annealing is raised to, say, 900 to 950 deg. C., which is about the usual Reaumur practice in common use in Europe, the appearance of the fracture is somewhat lighter in shade than "Black-heart," and the graphite is larger in size, and it is incidently lower in total carbon by reason of the higher temperature of annealing under greater oxidising conditions.

This difference in fracture appears to be entirely due to the fact that the lower temperature of 700 deg. C. is on or just above the lower critical point, whilst the higher temperature of 900 to 950 deg. C. is a little more than half way from this temperature towards the higher critical point at which the greatest precipitation of graphite takes place after solidification commences.

Thus we have an illustration in the annealing of malleable cast iron showing the difference in size of graphite entirely owing to a rise in temperature from 700 to 900 deg. C. when annealed for several days and allowed to cool slowly.

In their investigations Charpy and Grenet used as their base a pure iron-carbon alloy to which additions of silicon were made. Their No. 1 sample (the base) was total carbon 3.60, silicon 0.07, and other impurities 0.04 per cent., which would be white in fracture.

Charpy and Grenet's Research.

With their No. 1 sample, which is practically pure iron and carbon, it was found that prolonged heating at 1,100 deg. C., *just below the higher critical point*, no separation of graphite took place, but at 1,150 deg. C., which is *just above their cooling critical points*, separation of graphite took place.

With an addition of silicon 0.27 per cent. up to 1,000 deg. C. no trace of graphite is to be seen, presumably the sample is still white in fracture, but graphite appears when heated at 1,100 deg. C.

With a further addition of silicon 0.80 per cent. traces of graphite appear at 800 deg. C., which still suggests an *original* white fracture even with this percentage of silicon.

With silicon 1.25 and 2.10 per cent. separation of graphite takes place at 650 deg. C., which presumably means *further* separation of graphite occurs.

These investigators also show that the longer the period of heating of each separate analysis, the greater the separation of graphite.

Their research amounts to essentially one connected with the precipitation of carbon in a pure

* A Paper presented to the Paris Foundry Congress.

iron-carbon alloy, followed by the influence of additions of silicon on this separation. From the work of these two investigators, the following silicon influence column can be compiled, and the author has supplemented this by columns showing the influence of sulphur, manganese and total carbon on graphitisation on annealing.

TABLE I.

	(1) Si.	(2) S.	(3) Mn.	(4) T.C.
1. The separation of G.C. or free carbon is induced at a temperature which is lower.	The higher the Silicon.	The lower the Sulphur.	The lower the Mn.	The higher the T.C.
2. The separation of G.C. once commenced will continue below that at which reaction is induced.	—	—	—	—
3. At a constant temperature the separation of G.C. is affected progressively at a rate which is slower the lower the temperature.	The lower the Silicon.	The higher the Sulphur.	The higher the Mn.	The lower the T.C.
4. The contents of C.C. which correspond to equilibrium at a given temperature diminishes.	When the Si. increases	With lower Sulphur.	With lower Mn.	The higher T.C.

Unfortunately Charpy and Grenet appear to have chilled their sample test bars at varying temperatures, and hence the fullest graphitisation on natural cooling is not stated, but only that at the temperature of chilling, which, as will be shown, does not represent the percentage of graphite in the metal just before chilling. If, however, the samples were quenched at different temperatures, those quenched at the highest temperatures would contain the highest amount of combined carbon and the less graphitic carbon. Whilst not showing the full percentage of graphitic carbon on slow cooling, each result does show the separation of free carbon even when the sample is chilled at different temperatures shown in Table II.

TABLE II.—*Showing the Separation of Free Carbon when the Sample is Chilled.*

Temperatures.	Sample No. 1.		Sample No. 3.	
	G.C.	C.C.	G.C.	C.C.
1170 ..	0.5	2.61	1.42	1.69
1100 ..	1.15	1.74	1.49	1.4
1000 ..	1.03	1.74	1.35	1.55
900 ..	—	—	1.91	0.90
800 ..	1.15	1.31	2.09	0.43
700 ..	1.87	0.43	2.56	0.38

Graphitisation Due to Cooling.

Tawara and Asahara (I. and S. Inst., May 1919) published some very interesting results in connection with graphitisation of cast iron. Their investigations on total carbon and graphitic carbon percentages under apparently the same conditions are irregular, and no satisfactory regular results could be shown by diagram from their tables. Comparable specimens were slowly cooled for 1½ hours, but even the sample which was quenched after 1½ hours' cooling contained total carbon 3.42 per cent., *graphitic carbon* 1.26 *per cent.*, and silicon 0.02 per cent. It is interesting to know that these investigators say (a) that graphite grains exist when graphite is produced in molten metal, though the mechanism of this development is not known, which confirm's the author's cooling curves published in 1911, and also confirms Moissan's belief that graphite can form in molten metal. (b) They also consider that the maximum temperature to which molten metal was raised on melting has no apparent effect on graphitisation, and (c) these authors also hold that whilst temperatures of the mould into which their specimens were cast has some effect on graphitisation, i.e., particularly at 1,100 deg. C., yet whether cooling metal immediately or on cooling after annealing at that temperature for three hours there is no difference in graphitisation.

In the author's own works' experience nearly 20 years ago he had a sample of white iron left cooling in the pig beds overnight under hot metal, and the following morning the sample* was perfectly grey, as shown in the following Table III:—

TABLE III.

Fracture.	Total Carbon.	Graphitic Carbon.	Combined Carbon.
	Per cent.	Per cent.	Per cent.
Practically white ..	3.30	0.10	3.20
Grey No. 4	3.30	2.58	0.72

This fracture was a grey "No. 4," showing much larger graphite than the fine condition known as amorphous carbon. This was undoubtedly due to the fact that slow cooling, or annealing through the higher critical point, 1,200 to 1,100 deg. C., for a longer period than if the pig had cooled down in the ordinary way, which clearly indicates that in annealing white iron the size of the graphite flake is dependent on the length of time the cooling metal is retained at the higher temperature, i.e., *particularly through the first arrest.* This is apparently at variance with Tawara and Asahara's "B" and "C" conclusions, which difference is probably due to the fact that in the author's sample, the pigs were more slowly cooled

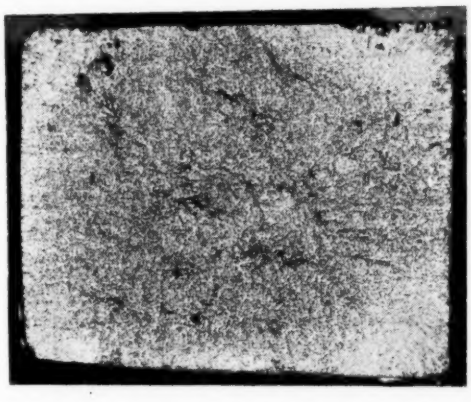

FIG. 2.—FRACTURE OF A CHILL-CAST BAR OF HIGH SI AND P CONTENT CAST AT 1,350 DEG. C.

through the critical temperature between 1,200 and 1,100 deg. C., and was in fact an example of graphitisation due to excessive slow cooling.

In ordinary foundry practice, in the case of a very soft cast iron, there was found to be practically no difference in the graphitisation in percentages, of test bars cast in different sizes from the same ladle of metal, as shown in Table IV., but the difference in the size of graphite is perfectly clear to the naked eye, and as seen under the microscope is clearly illustrated in the micrographs of the 1-in. and ¼-in. bar taken at 200 dias., shown in Fig. 1.

TABLE IV.—*Showing Carbon Conditions in Varying Sized Test Pieces.*

Test Bars.	T.C.	G.C.	C.C.
1 in. sq.	3.01	2.61	0.40
½ in. sq.	3.26	2.83	0.38
½ in. sq.	3.19	2.85	0.37
¾ in. sq.	3.06	2.69	0.37

The silicon in these bars was 2.50 per cent. and the phosphorus 1.50 per cent., so that the results of these practically constant total and combined carbons can only be applied to cast iron high in silicon and phosphorus, but had the silicon been lower, say nearer 1.00 per cent., it would be ex-

* See "Foundry Trade Journal," March 20, 1923, page 258, Fig. 3.

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pected that the combined carbon in the ¼-in. bar would be much higher than that in the 1-in. bar, entirely owing to more rapid cooling.

This difference in size of graphite due to rapid cooling raises an interesting problem in the theory of graphitisation. Moissan lays great stress on the influence of pressure on rapid cooling in producing diamonds, which shows that pressure as a factor must be considered even at lower temperatures than necessary to produce these. The greatest pressure is caused in two ways: (1) rapid cooling by chilling, and (2) absence of silicon, because the presence of silicon *decreases the contraction* of iron and therefore decreases the pressure on cooling. Further, it is well known that the higher the temperature from which cast iron is cooled by chilling the less the percentage of free carbon present, suggesting that the carbon other than free carbon is present in colloidal solution.

This is illustrated in Fig. 2, which is a photograph of the fracture of a bar 1¼ in. x 1 in. cast in chills, the silicon and phosphorus being high, and the metal cast at a very high temperature, about 1,350 deg. C.

The fracture was white only on the edge, but shows specks of graphite even on the edge near the chill; a mottled fracture is immediately behind the white and is grey in the centre of the bar. The graphite is more clearly seen in the unetched micrographs at 25 dias., as shown in Fig. 3, which gives (a) the edge, chiefly white iron with specks of graphite; (b) mottled iron, and (c) the centre or grey areas. In none of these areas is the true graphite flake shown, even the grey portion showing graphite in patches, which are smaller nearer the surface.

The influence of pressure considered together with the fracture and micrographs of the specimen just described, where, even with high silicon, the graphite is in a very fine state of division, suggests that the pressure in the grey centre was not sufficient to bring the carbon into colloidal solution, but was still sufficiently great to retain the free carbon in a very finely divided form. Had very little silicon been present the pressure on contraction would have been greater, thus splitting up the carbon into its finest state of division on cooling.

In the Journal for March 29 this year (page 258) the author showed three fractures illustrating fine graphite, flake graphite and the intermediate or "star" crystallisation of graphite. This intermediate crystallisation was first mentioned by the author before the Iron and Steel Institute in 1911, and has recently been confirmed by Mons. Paul Girod, of Ugine, a well-known investigator of iron-carbon alloys.

This intermediate or "star" crystallisation of graphite can also be obtained from close-grained or even mottled iron when it is exposed to working temperatures and conditions as in Diesel engine cylinders, or when the iron is exposed to a high temperature in very slow cooling.

Graphitisation in Molten Metal.

In preparing his Paper for the Iron and Steel Institute in 1906, the author discovered that the longer the iron remained molten the greater was the percentage of graphite. This is shown in the following table:—

TABLE V.—*Influence of Time on Graphite Precipitation.*

	Time Molten.		
	(1) 3 hours.	(2) 4½ hours.	(3) 5¼ hours.
T.C.	4.03	4.81	4.73
Gr. separation ..	3.00	3.84	4.03
Si.	0.024	0.04	0.07

Under the same conditions, had any of these samples been raised to the temperature of 1,400 deg. C. and immediately cooled, they might have been nearly white, but as will be seen from Table V., graphitisation takes place whilst the metal is molten.

This confirms the case the author met with some years ago. The combined carbon of a large casting was little more than a trace, and from the irons used, including steel, a combined carbon of 0.30 to 0.40 per cent. would have been expected, but as it was necessary to keep the molten metal in one of the ladles for over an hour, no doubt graphitisation took place as suggested in Table V. From the conclusions just quoted from Tawara and Asahara it would appear that there is a greater influence on graphitisation at, or just above, the critical point—about 1,150 deg. C. being the recalescence of graphite—than at just below this critical temperature, in other words at, say, 1,100 deg. C., and under it is more a question of separation of graphite by annealing.

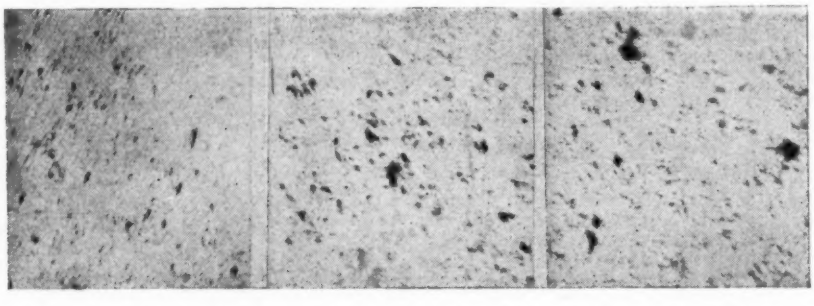

FIG. 3.—UNETCHED MICROS AT 25 DIAS. THE FIRST IS PRACTICALLY WHITE WITH FEW SPECKS OF GRAPHITE BEING TAKEN FROM THE EDGE. THE SECOND IS MOTTLED AND THE THIRD IS FROM THE CENTRE AND IS GREY.

Graphitisation Due to Primary Temperature.*

Moissan discovered that graphite can be produced at 910 deg. C. if the period was sufficiently long, and as modern blast furnace temperatures far exceed this it will be seen how valuable are his researches when applied to blast furnace practice, as they throw quite a new light on the condition of carbon in iron, and open up a wide field for further investigation.

As a practical illustration of the application of Moissan's conclusions on the influence on graphite of primary temperatures, the author was recently interested in the production of two successive casts of electrolytic† pig-iron. The analyses of the two casts are given in Table VI., and the two fractures are shown in Fig. 4:—

TABLE VI.—*Giving Composition of two Electrically Melted Pig-irons exhibiting different fractures.*

	A.	B.
	Per cent.	Per cent.
Total Carbon	3.11	3.44
Silicon	0.36	0.61
Sulphur	0.068	0.068
Phosphorus	0.19	0.19
Manganese	0.45	0.45
Fracture	White.	Grey.

Whilst the analyses are very similar and in themselves offer no suggestion as to the difference in fracture, the explanation of why one fracture was white and the other grey is that the grey fracture was produced at a higher *initial* temperature.

* The Author's views on this subject were set out in the "Foundry Trade Journal," March 29 issue, page 258, *et seq.*, which for the purpose of this Paper the Author has condensed.

† We believe the Author means electrically smelted pig-iron, as we cannot imagine such a composition being electrolytically produced.

In 1911 Ruff & Goecke published some valuable investigations in "Metallurgie" in connection with iron and carbon, and, as will be seen from Table VII., they found that at a temperature of 2,220 deg. C. iron can hold total carbon 9.64 per cent., or the equivalent of practically Fe_2C.

TABLE VII.—*Ruff and Goecke's Table.*

Temperature	G.C.	C.C.	T.C.
1 .. 1220	0.60	3.939	4.579
2 .. 1519	1.52	3.939	5.459
3 .. 1623	2.14	3.63	5.77
4 .. 1823	2.41	4.21	6.62
5 .. 2020	2.38	4.57	6.96
6 .. 2220	3.31	6.29	9.64
7 .. 2320	5.51	3.07	8.58
8 .. 2475	1.75	6.03	7.81

This table shows the temperatures to which these investigators raised various samples of iron, and which were quenched from the temperatures given above, and the total carbon, graphitic carbon and combined carbon. Again had these samples been allowed to cool slowly undoubtedly there would have been considerably more graphite present, and No. 6 particularly would suggest that Roozeboom appears to have been very nearly correct when he considered that iron could hold more carbon than the eutectic percentage of 4.30 per cent.; in fact, the Fe_2C percentage of 6.66 per cent.

It may be argued that the reason for the presence of graphite in the eight samples of Table VII. was that the total carbon was in excess of the eutectic of about 4.30 per cent., but this argument falls to the ground in view of the fact that the combined carbon in Sample 6 was 6.29 per cent., which is very near 6.66 per cent.

In 1910 Foster (West of Scotland I. and S. Inst.) gave an example in which he had melted mild steel in the presence of carbon at the temperature of the electric arc, and the molten metal was purposely thrown on to a metal plate to chill, yet despite this and a silicon of only 0.098 per cent. the fracture was perfectly grey. The analysis was: T.C., 4.665; Gr., 2.136; C.C., 2.259; Si., 0.098; S., 0.073; P., 0.063, and Mn., 0.454 per cent. Had this sample been allowed to cool gradually, as in the case of pig-iron, possibly very little combined carbon would have been present.

FIG. 4.—FRACTURES FROM THE TWO IRONS SHOWN IN TABLE VI.

The influence of primary temperature and time in this experiment shows the influence of high temperature on graphite in producing grey iron.

Percy quotes Karston as having, in 1846, found that iron could take up total carbon 5.93 per cent., but no mention is here made of the fracture of the iron.

All these facts have a most important bearing on the grading of pig-iron as set out in the author's discussion of M. Siegle's Paper in Manchester in June last. There is no connection by which it is possible to evolve a grading of, or use a pig-iron by carbon-silicon balance. All such formulæ are apparently based upon the volume percentage of carbon which has not yet been determined, and it will be very difficult to obtain a factor to convert carbon by weight to carbon by volume, because, as Moissan has shown, when iron contracts by rapidly cooling, carbon passes from a density of 2 to 3.5. In addition to this in blast furnace practice the temperature of smelting and the length of time the iron is in the blast furnace make the control of total carbon impossible, as also the control of the ratio of graphite to combined carbon.

Growth of Graphite.

It is well known that large flake graphite is produced at high temperatures in the blast furnace, and it has already been stated that tem-

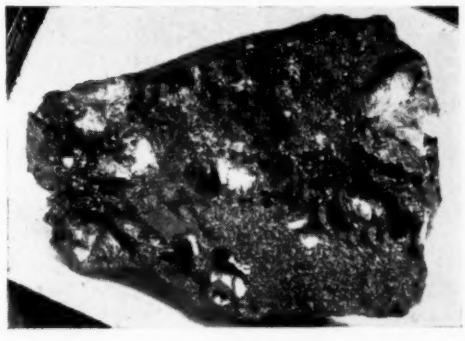

FIG. 5.—FRACTURE OF CAST IRON EXHIBITING VERY LARGE GRAPHITE FLAKES THROUGH SLOW COOLING.

perature at which blast furnaces are worked chiefly controls carbons and their condition. As further showing and emphasising the effect of temperature and rate of cooling, Fig. 5 gives a reduced photograph of a fracture of cast iron cooled under most abnormally slow conditions, and showing a very large flake, much larger than is found in an ordinary No. 1 pig-iron. This illustrates in an extreme manner the influence temperature can have on the growth of the graphite flake.

It would not be fitting to close this Paper without a reference to the splendid work done and example set by M. Siegle in his Paper, "Notes on Carbon in Foundry Irons and Castings: Utility of Control and Practical Difficulties," given before the Institute of British Foundrymen, in boldly referring to the connection between carbon and iron, and frankly admitting the difficulties in compiling a formula which would simplify the grading and use of pig-iron. These frank acknowledgments appeal to the pig-iron manufacturer, and not only simplify any discussion with them on grading, but lead to a greater co-operation by the ironmaster than would be possible by insisting on a theoretical form of grading. It was M. Siegle's Paper which suggested this one, which is intended to show in detail that graphitisation is not due entirely to chemical composition, but that "temperature," both primary and secondary, and "time" are most important factors. It must also not be overlooked that high temperature graphite, such as found in very open pig-iron, will continue to show its influence in the foundry because a close casting of moderate section cannot be obtained with an open iron.

There will be no satisfactory British method of grading pig-iron except by *fracture and analysis*, the fracture representing not the percentage of total carbon and graphite, etc., but the *character* of the graphite.

The author wishes to thank Mr. Gerald S. Bell, B.A., of Robey & Company, Limited, Lincoln, for the sample and analyses of Table V.; Mr. W. H. Poole, of the Keighley Laboratories, Limited, for the sample of which the photograph is given in Fig. 5; and his son, Mr. C. H. Adamson, for preparing the photographs and micrographs given in the Paper.

The Use of the Small Converter for the Production of Large Steel Castings.*

By Comm. Ing. C. Vanzetti, C.B.E. (Milan).

Suitability of Processes.

For steel foundry work, crucibles, the small converter, open-hearth furnaces, or electric furnaces may be used for the production of steel castings. Nowadays the crucible is employed only for special products, for which purpose it is being gradually superseded by the electric furnace.

For the production of high-quality castings, the small converter — generally acid-lined — requires raw material of the best quality, and a much higher proportion of pig-iron than of steel scrap, the loss in melting being considerable. The steel product, on account of the high temperature, may be very soft and quite suitable for small castings, but high quality cannot always be assured. Nevertheless, the small converter is still widely used in the countries where coke and pig of good quality are obtainable at a reasonable price. Its application is very simple, and it permits of intermittent operation alongside of a cupola and is well adapted for service in small foundries.

The Siemens-Martin furnace does not permit in general of obtaining easily a steel sufficiently hot for small castings, and continuous running is a necessary condition for its operation. It is not a simple matter—in fact, with the basic furnace it is very difficult—to tap the metal at intervals into the ladle, as is required in ordinary foundry work where it is not possible to pour hundreds of castings from a single ladle containing many tons of steel.

The electric furnace can be most efficiently used where the charge consists only of steel scrap. It works at a sufficiently high temperature and a product of the desired quality can be obtained. Without doubt this is the type of furnace best adapted for the production of castings of every variety, but the excessive cost of electric power may prohibit its use, and in any case it requires continuous operation.

A steel foundry producing from 200 to 600 tons per month can be very well served by three open-hearth furnaces or electric furnaces of 2 to 3 tons each, two of which are in operation, while one is in reserve. Under such conditions a foundry can produce castings of a maximum gross weight of 5 to 7 tons each, or a net weight of, say, 3 to 4 tons.

For the production of very heavy castings, such as are required for large warships or for anvil beds of large hammers or frames of rolling-mills, and such like, which require up to 50 tons or more of molten metal, open-hearth furnaces of sufficient capacity are generally used. But furnaces of such a size are not best adapted for ordinary foundry work, being more suitable for making ingot steel, and steelworks which make ingots are not generally equipped for making castings. Consequently, there are not many works of importance which can normally manufacture castings of more than 4 to 5 tons.

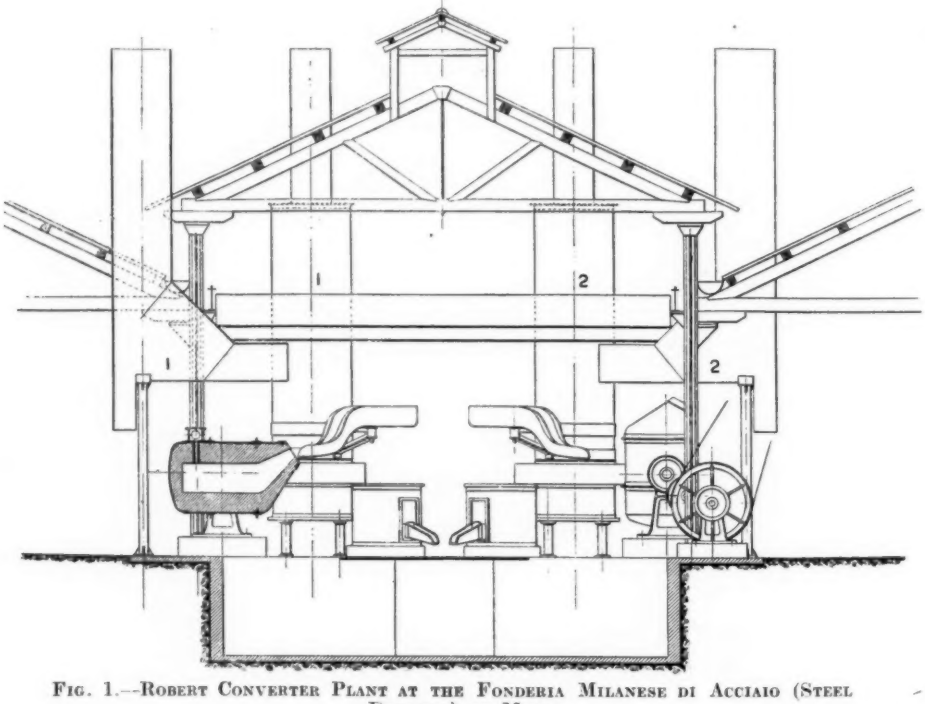

FIG. 1.—ROBERT CONVERTER PLANT AT THE FONDERIA MILANESE DI ACCIAIO (STEEL FOUNDRY) OF MILAN.

Plant Available.

The Milan Steel Foundry, established in 1888 for the production of light steel castings with the small Robert converter, worked for several years with no other apparatus. About 1895, when the increased number of orders made continuous working possible, two small open-hearth furnaces of 3 and 4 tons respectively were installed, and later a third one of 7 tons. In 1910 electric furnaces were introduced—at first three Stassano furnaces of 1 ton each; afterwards two Electro Metals furnaces of 3 to 3.5 tons were built. During the war several more electric furnaces of the latter type were installed. At present the foundry is served almost exclusively by Electro Metals furnaces, using a F.M.A. furnace (or our own design) for short periods when the Electro Metals furnaces are under repair.

In exceptional circumstances, for instance during the winter, when in Lombardy hydro-electric power fails, and it becomes necessary to use the more costly power derived from heat sources, one of the small open-hearth furnaces is started in addition.

Already in 1894 we began the production of large castings, using the converter alone. At the Milan

* Extracted from a Paper presented to the Milan meeting of the Iron and Steel Institute.

works, three Robert converters of about 1 ton each were installed with two cupolas each capable of melting 6 tons of pig per hour. One of the three converters has never been in operation, and is held in reserve. There are two piston blowing-engines, one driven by steam, the other by electricity, each capable of delivering 90 cub. metres of air per min. at a pressure of 40 centimetres of mercury. One of these is in operation while the other is in reserve.

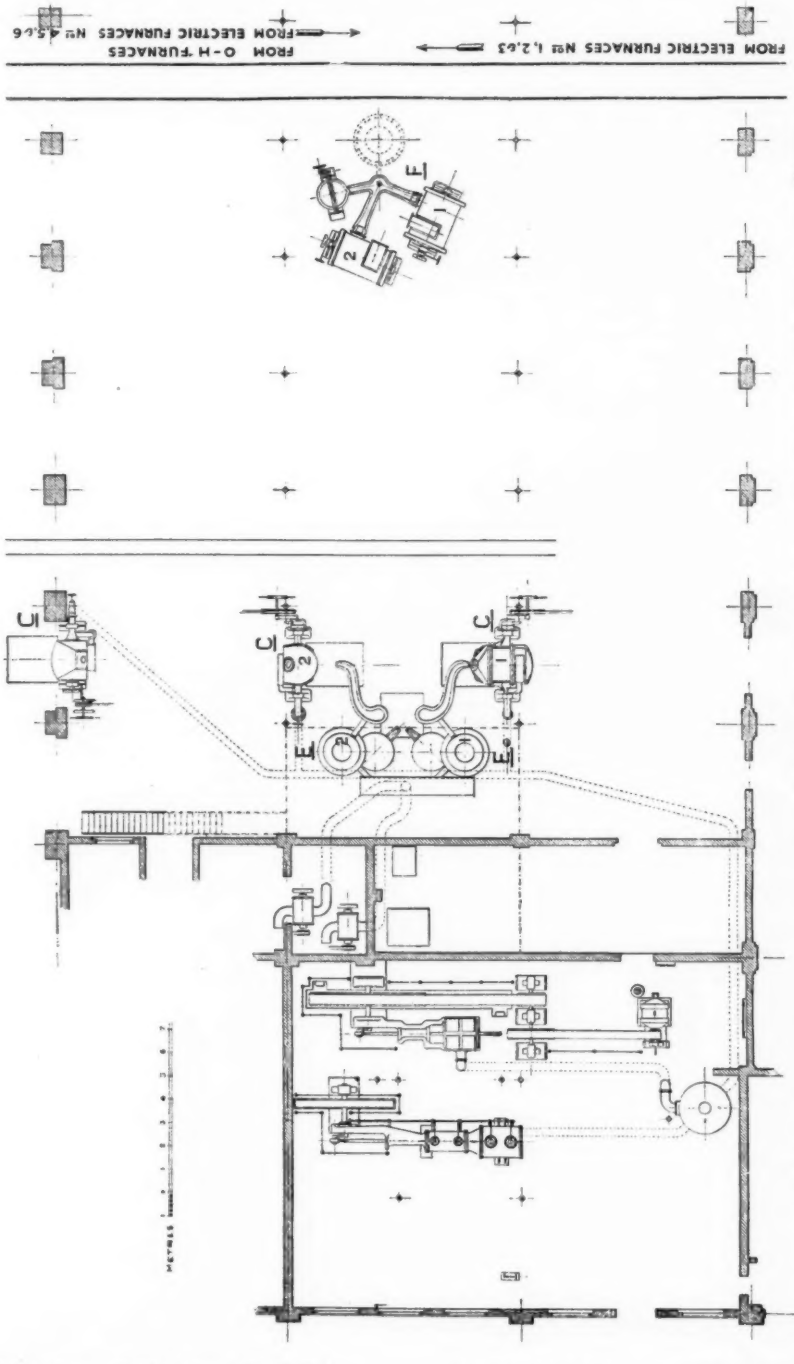

FIG. 2.—PLAN SHOWING ARRANGEMENT OF ROBERT CONVERTER PLANT AND AUXILIARY APPARATUS AT THE FONDERIA MILANESE DI ACCIAIO.

Making Large Castings from Small Units.

In the first years of the operation of the plant, castings of about 2 tons maximum were produced, working with one converter only. Three successive heats were collected in the ladles, the first heat being teemed into a 1-ton ladle, and the second into a 3-ton ladle. When the third heat was ready, the first was tipped into the 3-ton ladle, and the 1-ton ladle was then brought again under the converter to receive the third heat. In 1894 it was believed we could accept the order for the two supporting brackets for the screws of H.M.S. *Marco Polo*. Each casting weighed 6 tons net, or about 10 tons gross. To avoid the chance of running short in making the first one, it was calculated that 12 tons of molten metal would be necessary.

At that time the foundry did not possess a travelling crane of more than 6 tons capacity, so that it was necessary to devise a tank receiver mounted on two standards into which to teem the steel. The casting of the first bracket was a complete success, insomuch that, for the second, it was decided to prepare only 8 tons of steel. The additional 2 tons necessary for the feeding-head were blown afterwards and poured direct into the runner forming the feeding-head. Two cupolas were kept in continuous operation, and two converters were worked alternately, the blowing-engine having to run continuously.

The result was so satisfactory that the firm then did not hesitate to accept orders for much more important castings. Most of the stems, stern frames, and rudder frames of Italian merchant ships and ships of war were cast by the method described, which naturally in the thirty years of our experience has been perfected to a high degree.

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On account of its convenience, the system in general has been retained to the present day. Recently, having to supply some large rings with an internal diameter of 1.50 metres, an external diameter of 2.50 metres, and 75 millimetres thick, which had to be absolutely sound and without the least defect, the author preferred, rather than cast them singly, to cast them in the form of large tubes, weighing about 30 tons each, out of which the rings were turned in the lathe, and all resulted perfectly good. From every tube it was found possible to turn one ring more than had actually been provided for, on account of the small amount of pipe due to feeding with hot steel for some time after teeming.

Notes on Procedure.

The Robert Foundry consists of three bays, each 10 metres wide, as shown in Figs. 1 and 2. At the end of the central bay the two cupolas are placed. The ladle for receiving the molten metal is run between the two cupolas and when filled is lifted by a special windlass to a height sufficient to enable it to tip the metal into either one of two sheet iron troughs which can be slewed on a swivel. Through these troughs it flows into the converters marked C. These latter are tilted by motors, but hand gear is also provided. A travelling crane ranging the whole length of the bay brings the steel ladle into position to receive the charge from the converters, and pour it into the receivers F, marked 1 and 2 (Fig. 2), which are suitably placed in the foundry for pouring the contents direct into the mould. The third converter is kept hot and remains in readiness in case of accident.

It will be understood that it is necessary to have the metal very hot and to work very rapidly, other considerations of economy having to be sacrificed

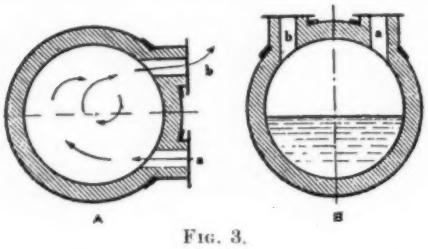

FIG. 3.

to these two conditions. On this account a higher proportion of pig than of steel scrap must be charged into the cupola, the quantity of coke for melting is increased, and the converters besides are furnished with eight instead of five tuyeres. A higher air pressure is thus required for blowing the converters, and this increases the loss in blowing.

It is customary to send the first heats of each converter to the foundry for ordinary castings, then, when a sufficiently high temperature is reached, the filling of the receiver is begun.

The blowing of the converter is stopped on the complete disappearance of the flame, which corresponds to a carbon content of 0.07 to 0.08 per cent. The additions of ferro-silicon and ferro-manganese are made in the ladle after teeming from the converter. The carbon is brought up to the requisite amount, adding in the receiver, if occasion requires, the proper quantity of molten pig taken from the cupolas.

The receivers are respectively of a capacity of 10, 12, and 15 tons. They are constructed of iron plate in cylindrical form, with their axes horizontal. They turn on two trunnions, and are furnished at the two opposite ends with two openings, as shown in Fig. 3. These are lined with a thick layer of refractory brick. Several hours before melting begins, the receivers are adjusted as shown in Fig. 3, A, and to the lower opening *a* is applied a portable burner. For the last two years burners fed with heavy oil have been used. The products of combustion escape by the upper opening *b*. The heating up is continued for several hours, so that when the first charge from the converter is ready, and the receivers are turned up as shown in Fig. 3, B, the lining is heated to a white heat.

When the receivers have been charged with the necessary quantity of steel, as much slag as possible is run off and a pouring spout of special form is attached to opening *a*, having a bore of 50 mm.

A Simple Heat Test.

Before proceeding to pour, the temperature of the bath is tested by an empirical, but practical, method. As is known, steel castings must be poured at the lowest temperature compatible with their dimensions. Before pouring, an iron washer about 12 mm. diameter is plunged quickly to a depth of about 6 in. in the metal in the receiver. If the steel is very hot, the piece will melt in a few seconds; if it is very cool, it will form a solid crust around the washer.

The foreman foundryman judges from the form or thickness of the disc how many seconds it should remain in the bath before melting. Three or four successive tests will sufficiently indicate the temperature of the bath. If it is rather low, pouring is proceeded with as quickly as possible, risking the formation of a skull in the receiver. If it is too high, the pouring is delayed until the temperature is judged to be correct. In general, as soon as the steel is poured into the receiver, the temperature is too high, and it is necessary to wait.

Some years ago, owing to an interruption in the electric current just when the receivers were three-quarters full, the work had to be stopped for three-quarters of an hour. There was a small skull in the receiver, but the casting came out perfect.

How Slag Inclusions are Avoided.

When the foreman foundryman gives the order, the receiver is tilted at top speed to prevent the outflow of any remaining slag along with the metal. If that occurs, one or two ladlesful from the electric furnace or open-hearth furnace are poured together into the funnel of the receiver, and generally the feeding of the casting through the runner is continued for some time.

Notwithstanding that the total loss of metal exceeds 20 per cent. and the converter is acid-lined, it has always been customary to use pig and scrap exceptionally free from sulphur and phosphorus. Before the war, washed coke of Belgian origin, almost sulphur free, was always used in the cupola. Now we have to be content with a less pure material, but we still obtain very satisfactory results, the products showing tensile strength from 29 to 32 tons per sq. in. with elongation equal to 20 per cent.

From detailed charge sheets accompanying the Paper it is shown that the chemical composition and mechanical properties of steel have improved after remaining a long time in the receiver. The steel as it comes from the converters contains considerable quantities of oxides and silicon in suspension. During the time it remains in the receiver, these impurities separate out partly by liquation, and partly by the reactions produced by the manganese and silicon content in the steel.

The converter not only provides a means for obtaining at short intervals a very hot steel in small and frequent quantities for feeding the runner, but it reduces very considerably the volume and weight which it is necessary to give to the feeding-head.

THE ENGINEERING & MERCANTILE COMPANY, LIMITED, of 61-62, Chancery Lane, London, W.C., have removed to 1, Bartlett's Passage, Bartlett's Buildings, Holborn, E.C.4.

CAMMELL, LAIRD & COMPANY, LIMITED, have secured a contract from the Great Indian Peninsula Railway for 77 motor and trailer coaches in connection with the electrification of the Bombay suburban lines.

THE LONDON OFFICE at 91, Bishopsgate, E.C., of Lamberg, Gibson & Row, Swedish iron agents, has been closed and the business at 4, Prudential Buildings, Pinstone Street, Sheffield, has been taken over by Messrs. A. E. Miles and W. T. Price.

HOLLINGS & GUEST, LIMITED, Thimble Mill Lane, Birmingham, have at the present time their hydraulic presses and pumps on order for various parts of the world, including China, India, East Africa, Australia, Gold Coast, etc. They have also a large number of presses and pumps going through the works for use at home, including a machine for the Portsmouth Dockyard.

IRON AND STEEL MARKETS.

Pig-iron.

MIDDLESBROUGH.—The general state of the pig-iron industry, not only on Tees-side, but throughout the country, continues extremely unsatisfactory, and is significantly illustrated by the production figures for August. This shows that the pig-iron output at 599,800 tons was more than 55,000 tons lower than in July. There has been a steady fall every month since the year's record of 714,200 tons was made in May. Both home consumption and export trade have suffered equally by the decline in demand for finished material and the consequent decrease in production in the foundry industry, while the quieter conditions now prevailing in the steel market are all contributory factors in the position. Cleveland pig-iron prices continue weak, and are now about upon a competitive basis with Midland for export business, but this trade is in a very stagnant condition. Probably there is barely one ton of Cleveland iron shipped compared with ten tons of hematite, and, apart from the chaotic currency conditions on the Continent, prices will have to fall further before there can be any revival in business. On 'Change this week prices were largely unchanged at last week's levels. No. 1 stands at 102s. 6d., No. 3 G.M.B. 97s., No. 4 foundry 92s. 6d., and No. 4 forge 90s. per ton.

There is a rather better tone in the home trade as regards hematite, some fair orders having been placed during the past week. Quotations at present are irregular, but with a firming tendency. For substantial parcels East Coast mixed numbers could, no doubt, still be done at 98s. 6d. per ton, but some makers are demanding up to 100s., and an average quotation would now be about 99s. per ton. In West Cumberland and North Lancashire Bessemer mixed numbers remain at the old figure of £5 10s. per ton delivered at Glasgow and Sheffield, £5 13s. per ton at Birmingham, and £5 10s. Wales. The closing down of a furnace for re-lining by Messrs. Gjers, Mills & Company, Limited, brings the number of hematite furnaces blown out since the end of June up to nine, but, on the other hand, Messrs. Bolckow, Vaughan & Company, Limited, have transferred a furnace from Cleveland iron to hematite. The number of furnaces now in blast on the North-East Coast is 39, of which 10 are on Cleveland, 12 on hematite and 17 on basic and special kinds of iron.

MANCHESTER.—Conditions in the local consuming trades continue depressed, and demand is too intermittent to be satisfactory from the producers' point of view, while the recent decline in pig-iron prices has, so far, had little effect in stimulating sales. The difference between the cost of Cleveland and Derbyshire foundry iron delivered in Manchester, which was from 25s. to 30s. at one time, is now only 10s. per ton. Sellers of Derbyshire iron, as a rule, keep to their former price of 92s. 6d. per ton at the furnaces at present, but there is some weakness, and the opinion is expressed by consumers that orders for tempting quantities might perhaps be placed at 90s. per ton on trucks.

THE MIDLANDS.—The outlook for smelters in this area continues unfavourable, and unless there is an improvement within a reasonable time it is quite probable that nine furnaces will have to be put out of action. The demands of the South Staffordshire finished iron trade are comparatively insignificant, and of the different branches of the foundry trade the only one in a fairly satisfactory position is that for builders' iron-foundry goods. Fair supplies are being sent to foundries producing this class of goods, and there appears to be a moderate trade with pipe-founders, while shipments to the Continent are still being made. Coke is reported to be in more plentiful supply, but no easier in price. Quotations: Northamptonshire No. 3 foundry, 90s.; Derbyshire No. 3 foundry, 92s. 6d., all net f.o.t. furnaces.

SCOTLAND.—Some small improvement in tone is reported in the local market, while consumers are said to be taking increased interest in current business, and though still preserving an attitude of caution, are buying a little more freely than of late. The quotation for Scottish No. 3 foundry pig is unaltered at £5 1s. f.o.t. furnaces, and makers continue to complain bitterly that this price is unremunerative, and are therefore striving to prevent a further decline. In spite of this, however, merchants are still inclined to take a bearish view, and are cutting the makers' prices, there being very keen competition for even the smallest order. No. 3 Middlesbrough is quoted at £5 3s. f.o.t. Grahamston, and No. 4 foundry 5s. per ton less. Continental foundry seems to have almost entirely disappeared from the market, and only odd parcels are on offer. There is a little more inqury circulating from abroad. The foreign shipments from the Clyde last week were 728 tons, as compared with 522 tons for the corresponding week last year. No. 3 Scotch is being offered at £5 6s. f.a.s. Glasgow.

Finished Iron.

In the South Staffordshire area, with the exception of makers of marked bars, who are fairly steadily employed, manufacturers of finished material generally are experiencing a period of extreme depression. This can be partically explained by the fact that in many sections of the trade steel has displaced iron to a disastrous extent, the heavy disparity in cost of the former, as compared with the latter, especially by foreign competitions, being a heavy handicap to the home producer. Slackness in the engineering and shipbuilding branches is a further adverse factor restricting demand for finished material, while the prices now obtainable are declared to be hopelessly unprofitable to makers. As illustrating the conditions of trade at the present time it may be noted that makers of fine quality iron, such as that used for ships' cables, are having a very quiet time indeed. Some of them, who in the past never knew what it was to be slack, are finding it very hard work to keep their plants employed three days a week. And the prices obtainable are still extraordinarily poor.

Steel.

Movements in the steel industry at the moment present little change in the general position, but the tone may be regarded as slightly more encouraging than has been reported of late. In the market for semi-products acid billets are on the quiet side, but for basic qualities, especially soft qualities, there is a little better demand. Slightly increased activity of demand may be noted for alloys as regards the less expensive metals, but, on the whole, business is quiet. The recent disaster in Japan may possibly have some effect on the market for alloys. There is certainly bound to be some business as a result of the reconstruction that will be necessary in Japan, and as soon as something like normal conditions can be resumed in that country orders are likely to be forthcoming. In the tinplate market a fair amount of business is passing, most works being comfortably booked up for a few weeks ahead. There is, however, not much doing on forward account. Current quotations are: Coke quality, IC 14 by 20, 112 sheets, 108 lbs., 23s. 1½d. per box; IC 28 by 20, 56 sheets, 108 lbs., 23s. 7½d. per box, with lights at ¾d. per lb. down from 108 lbs., net cash, f.o.b. Bristol Channel ports.

Scrap.

Business in most classes of scrap material, though comparatively quiet, appears in some districts to indicate signs of improvement, this tendency, perhaps, applying more particularly to cast iron in its various qualities. This is notably the case in the Scottish market, where it is the only material which remains fairly firm and shows prospects of a rise. Inquiries are fairly good, and the consumption more than covers the material available. Heavy machinery cast-iron scrap and scrap railway chairs run about 92s. 6d. to 95s., and ordinary cast-iron scrap 82s. 6d. Light metal and furnace fire bars are at 65s. On the other hand, the demand for cast scrap in Lancashire remains poor, and the prices have not been altered. It is perhaps some satisfaction to have them on a rock-bottom basis, for the limited demand during the last two or three months has not been able to force them down. Dealers still quote from 80s. to 85s. per ton, according to quality, for broken machinery metal, and the sales are small. It is, however, probable that good cast scrap metal, at present prices, is a particularly sound material to hold, and even if pig-iron should fall another 10s. per ton cast scrap would still be cheap.

Metals.

Copper.—During the past week the standard copper market has presented a fair amount of activity, with values at levels slightly more favourable to buyers for either prompt or forward metal. According to all reports, trade in the United States is expanding, and this leads to the hope of well-maintained prices, in spite of the fact that production at present is somewhat

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METAL MARKETS—*continued.*

in excess of requirements. The demand, meanwhile, for export is slow, and this is not surprising in the present critical state of affairs in Europe. Current quotations :—*Cash* : Thursday, £63; Friday, £62 15s.; Monday, £62 7s. 6d.; Tuesday, £62 2s. 6d.; Wednesday, £62 2s. 6d. *Three Months* : Thursday, £63 15s.; Friday, £63 7s. 6d.; Monday, £63 2s. 6d.; Tuesday, £62 15s.; Wednesday, £62 15s.

Tin.—This section of the market has developed increasing strength, with values last week recording upwards of £200, while subsequent fluctuations were very little below that high level, movements justified by recent statistics and the revival of American demand. The position is, however, to some extent due to heavy speculative buying following the enormous destruction of stocks of metal in the Japanese disaster, the extent of which is at present not ascertained. Current quotations :—*Cash* : Thursday, £195 17s. 6d.; Friday, £193 10s.; Monday, £193 10s.; Tuesday, £197 5s.; Wednesday, £198 2s. 6d. *Three Months* : Thursday, £196 15s.; Friday, £194 10s.; Monday, £194 10s.; Tuesday, £197 15s.; Wednesday, £198 15s.

Spelter.—The market for this metal continues strong and active. At the present time galvanisers, after their recent purchases, are not interested, but the general opinion appears to be that the supplies which they are carrying must be small, and hence further large purchases cannot be long delayed. With Continental producers not willing sellers, and supplies of ore remaining limited, the market has a very firm appearance. Current quotations :—*Ordinary* : Thursday, £33 12s. 6d.; Friday, £33 2s. 6d.; Monday, £32 17s. 6d.; Tuesday, £32 15s.; Wednesday, £33 2s. 6d.

Lead.—In the market for soft foreign pig the influence of the Japanese disaster has also been evident. The East is always a large buyer of lead, and in the expectation that still larger quantities of Australian and Burmah metals will be required in that quarter prices have advanced uninterruptedly. Arrivals in this country have not been heavy, and favourite brands command a high premium. Current quotations: *Soft foreign (prompt).* : Thursday, £25 15s.; Friday, £25 15s.; Monday, £25 12s. 6d.; Tuesday, £25 7s. 6d.; Wednesday, £25 7s. 6d.

Trade Talk.

BARCLAY, CURLE & COMPANY, LIMITED, have secured an order for two P. & O. liners of 15,000 tons each.

AT AN ESTIMATED cost of £2,100, the Callendar Iron Company, Limited, are to erect an enamelling shop at their works.

THE ENGINEERING AND SHIPBUILDING TRADES FEDERATION has decided to apply for a 10s. weekly advance on the wages of men employed in shipyards.

GUEST, KEEN & NETTLEFOLD, LIMITED, are reported to have started negotiations to purchase several railway steel, nut, and bolt works in the Darlaston district of Staffordshire.

A FIRE OCCURRED at the works of Metropolitan-Vickers Electrical Company, Limited, in Brightside Lane, Sheffield, on Tuesday, damage being done to the paint and general store shops.

THE BARROW HEMATITE STEEL COMPANY, LIMITED, have posted notices informing their employés that after one week all contracts will cease, and employment be from day-to-day only.

THE WHOLE OF THE SHARES in the old-established foundry and engineering business of Messrs. Herring & Son, Limited, of Chertsey, have been purchased by Mr. Trewhella, of Belsize Lane, London, N.W. The negotiations were carried through by Mr. H. G. Butcher, of Messrs. Henry Butcher & Company, 63 and 64, Chancery Lane, London, W.C.2.

THE QUARTERLY ASCERTAINMENT under the sliding scale in operation in Cumberland and North Lancashire gives the average selling price of West Coast hematite mixed numbers at £5 9s. per ton, compared with £5 16s. per ton, a reduction of 7s. per ton. The wages of blastfurnacemen accordingly fall by 8¼ per cent. to 49¼ per cent. on base rates. Bonus earnings in the north and south of the district are 86¾ per cent. and 81⅔ per cent. respectively.

IN THE HALF-YEARLY REPORT of the Central Ironmoulders' Association the number of unemployed is shown as 560 as against 714 three months ago, representing a decrease of 154 for the quarter. Commenting upon the reduction, the executive say that it gives indication of the tendency towards an improvement in trade, though at a slow rate. The membership at present stands at 6,713 as against 6,664 at the end of March, an increase of 49. The total funds of the association have increased by £1,860 in the last three months, and now amount to £10,343.

Company News.

E. L. Price, Limited, 34, Fenchurch Street, London, E.C.—Capital £10,000 in £1 shares. Engineers.

Sir W. G. Armstrong, Whitworth & Company, Limited.—Interim dividend on ordinary shares, 6d. per share, less tax.

Bullivant & Gimson, Limited.—Capital £5,000 in £1 shares (1,500 5 per cent. cumulative preference and 3,000 ordinary). Engineers.

Edward D. Payne, Limited, 102, Irving Street, Birmingham.—Capital £1,500 in £1 shares. Iron and general founders, etc.

Stewarts & Lloyds, Limited.—Interim dividends for half-year, 6 per cent. per annum on preference shares, and 10 per cent. per annum on preferred ordinary shares.

Wright, Bindley & Gell, Limited.—Balance, including amount brought in, £13,588; dividend, 5 per cent. for year on ordinary, free of tax; carried forward, £2,143.

S. S. Whiteley & Company, Limited, Eglington Works, Isandula Basford, Nottingham.—Capital £5,000 in 3,000 preference and 2,000 ordinary shares of £1 each. General engineers. Directors: Mrs. Alice M. Whiteley and R. I. Whiteley.

Elliott's Metal Company, Limited.—Profit, £85,553; brought forward, £26,865; dividend, 5 per cent. per annum on preference shares, subject to tax; ordinary dividend, 3s. per share for year, subject to tax; write off balance of expenses of fusion with Muntz's Metal Company, Limited, £1,805; carry forward, £32,904.

Gazette.

A. E. WILSON, 84, Dewhurst Road, Syke, foundry manager, is paying a first and final dividend of 1s. 6½d. at Official Receiver's, Manchester, September 19.

TRADING IN THE STYLE of Tolley, Sons & Bostock, Messrs. R. M. Tolley and W. H. Bostock, Darlaston Steel and Ironworks, Darlaston, iron and steel manufacturers, have dissolved partnership.

A RECEIVING ORDER has been granted in the case of W. J. Andrews, trading as Weydon Hill Ironworks, Castle Street, and Red Lion Lane, Farnham, engineer. Examination : Guildhall, Guildford, October 2, at 11.30.

AN APPLICATION FOR DISCHARGE from bankruptcy proceedings by W. H. Pease, Hastings House, Norfolk Street, Strand, and Welwyn Garden City, engineer and governing director, will be heard at Bankruptcy Court, October 16, at 11.

TRADING IN THE STYLE of E. B. Parr & Company, Messrs. E. G. R. Parr and W. E. R. Parr, 224, Bermondsey Street, S.E., engineering, electrical and general pattern model makers, millwrights, etc., have dissolved partnership. Debts by E. G. R. Parr, who continues the business.

British Pig-iron and Steel Output.

The production of pig-iron in Great Britain in August amounted to 599,800 tons, compared with 655,100 in July and 411,700 tons in August, 1922. The furnaces in blast at the end of the month numbered 196, a further decrease of 10 during the month. The output of steel ingots and castings amounted to 582,700 tons, compared with 624,300 tons in July and 528,400 in August, 1922.

The following table shows the average monthly production of pig-iron and steel in 1913, 1920, 1921, and 1922, and in each month of the present year :—

	Pig-iron.	Steel ingots and castings.
	Tons.	Tons.
1913—Average monthly ..	855,000	639,600
1920— " " ..	669,500	755,600
1921— " " ..	218,000	308,600
1922— " " ..	408,300	486,000
1923—January	567,900	634,100
February . ..	543,400	707,100
March	633,600	802,500
April	652,200	749,400
May	714,200	821,000
June	692,900	767,700
July	655,100	624,300
August	599,800	582,700